INTEGRATED PEST IMPACT ASSESSMENT SYSTEM: DEVELOPMENT AND OPERATIONS COORDINATION

Gregory J. Buhyoff and Terry C. Daniel

Integrated Pest Impact Assessment System:
Development and Operations Coordination

Cooperative Agreement 28-C4-320

Final Report

Submitted to:

USDA Forest Service, Forest Pest Management
Methods Application Group, Fort Collins CO

September 15, 1988

by

Gregory J. Buhyoff
Professor
School of Forestry and Wildlife Resources
Virginia Tech, Blacksburg VA

and

Terry C. Daniel
Professor
School of Renewable Natural Resources and Dept. of Psychology
University of Arizona, Tucson AZ

FINAL REPORT OVERVIEW

This final report constitutes the final obligations under the stipulations of cooperative agreement #28-C4-320. This cooperative agreement is entitled "Integrated Pest Impact Assessment System (IPIAS): Development and Operations Coordination." Under the terms of this contract Gregory J. Buhyoff, of the School of Forestry and Wildlife Resources at Virginia Polytechnic Institute and State University, in cooperation with Dr. Terry C. Daniel who acted as the prime subcontractor were to accomplish the following objectives during the period FY 84 to FY 88.

1. Insure overall coordination and review during development and testing of the pest impact system.
2. Identify user interface needs.
3. Identify existing forest stand and mountain pine beetle models.
4. Identify national and Washington office information needs.
5. Evaluate existing models with respect to user interface needs.
6. Evaluate existing data.
7. Define data needs for the integrated pest impact assessment system.
8. Define criteria for pilot project and select pilot project forest.
9. Demonstrate feasibility and determine Forest Service acceptance of IPIAS.
10. Technology transfer as appropriate and develop a draft technology transfer plan.

All of these objectives, in fact, have been met and the following will document the work accomplished which was aimed at meeting them.

The next section provides summaries of the accomplishments of each fiscal year from FY 84 through FY 88 and also documents supporting activities. Detailed descriptions of work accomplished during each fiscal year follow as separate sections in this report.

Fiscal Year Accomplishments

Fiscal Year 1984:

Work during this year was aimed at identifying user interface needs, existing models and national information needs. A survey was conducted of both administrators and users of forest information systems and models. This work was accomplished primarily by the use of a formal written questionnaire and through personal interviews. In addition, several Washington office visits were made during the Spring, 1984, and an IPIAS planning session for the project was attended in Fort Collins in August of the same year. An additional steering committee meeting was held in Eugene, Oregon, in March of 1984 which Dr. Buhyoff attended. Dr. Daniel participated in a contagion model planning meeting in Colorado during June of 1984. Analyses of the user-needs survey are contained in the following FY 84 detail section.

From the work conducted during this year was a publication entitled "Integrated Pest Impact Assessment System Development: Impact Model Inventory and Use Survey", by G. J. Buhyoff, T. C. Daniel, W. B. White, and D. O. Hunter, Report No. 86-5, Forest Pest Management Methods Application Group, Fort Collins, Colorado (Appendix A).

Fiscal Year 1985:

The work during this year was aimed at evaluating the potential for interfacing models into a broad-based decision-support system and evaluating the types of existing data bases which existed for use by such a system. In addition, a pilot test site was to be selected for the development of prototyping of an IPIAS framework. Many possible models were identified for potential use by IPIAS in relation to the site which was to be selected for the pilot project. During this year, the Red River District of the Nezperze National Forest was selected as the pilot test location. Geographic information systems, stand inventory data, and a variety of models including wildlife, fisheries, timber, and stand simulators were evaluated for their potential of being integrated into a pest impact assessment system. Trips were made to the Red River district of the Nezperze National Forest in

order that Forest Service personnel could be involved in the development and prototyping of this system. The initial computer code and a system framework were developed during this fiscal year and, in fact, a skeletal working version of the system was running by year's end. Further, the model inventory and user needs phase of the project (FY 84 work) continued during this year so that full consideration could be given to a wide variety of potential components for the final system.

Dr. Daniel and Dr. Buhyoff attended two formal meetings relating to both the planning and steering committee functions of this program. Several trips were made to the Nezperze National Forest by both Drs. Daniel and Buhyoff.

Three publications resulted from the foregoing work during 1985 (see also Appendix A).

Daniel, T. C. 1985. Modeling Social Impacts of Forest Management. [In - Recent Advances in Spruce Budworms Research -Proceedings of the CANUSA Spruce Budworms Research Symposium, C. J. Sanders, R. W. Stark, E. J. Mullins, and J. Murphy (Eds.). Ottawa, Ontario, Canada.] pp. 255-256.

Buhyoff, G. J. and Daniel, T. C. 1985. Forest Management Models: A Review and User Needs Assessment. [In - Recent Advances in Spruce Budworms Research -Proceedings of the CANUSA Spruce Budworms Research Symposium, C. J. Sanders, R. W. Stark, E. J. Mullins, and J. Murphy (Eds.). Ottawa, Ontario, Canada.] pp. 257-258.

White, W. B., Daniel, T. C. and Buhyoff, G. J. 1985. Integrating Social Impacts Assessment into Forest Management and Planning. [In - Recent Advances in Spruce Budworms Research -Proceedings of the CANUSA Spruce Budworms Research Symposium, C. J. Sanders, R. W. Stark, E. J. Mullins, and J. Murphy (Eds.). Ottawa, Ontario, Canada.] pp. 259-260.

Fiscal Year 1986:

Work to be completed during this fiscal year was aimed solely at defining the data needs for the integrated pest impact assessment system as per contract #28-C4-320. Since much of the work involving the definition of data needs was completed prior to this time, Drs. Buhyoff and Daniel involved themselves in a variety of tasks which were aimed at early completion of future objectives as well as work aimed at supporting the concept of an integrated pest impact assessment system.

It was decided that a visual impact assessment module should be developed for IPIAS. This work would be in addition to that work originally called for under contract #28-C4-320. Source code and documentation was obtained for PREVIEW, the perspective plotting program. Considerable time was invested in rewriting the program in the commonly used FORTRAN 77 and in cleaning up a variety of algorithm problems from previous programmers. The program was put up on a Data General MV 10,000. This program then became portable to the Forest Service Data General environment. Thus this greatly expanded the availability of this particular program to Forest Service units. The most essential modification made to this program was to replace the data entry algorithms with an automated entry interface so that the MOSS/IPIAS data base could be used. In addition, much of the time during FY 86 was spent in developing a scenic beauty model which would operate within the Red River District environment. Work was aimed at developing a geographic information system (MOSS) driven vista scenic beauty model that would be reliable and yet sensitive to subtle changes in the vegetation cover characteristic of the Red River District. A publication entitled "Linking Computer Generated Forest Visual Simulations to Geographic Information Systems", by Robert M. Itami and Terry C. Daniel resulted (see appendix A).

Other allied activities also occurred during FY 86. Dr. Buhyoff attended a workshop on the potential uses of artificial intelligence technologies in impact assessment systems such as IPIAS. This workshop was held at Texas A & M University, Department of Entomology, in December, 1985. Dr. Buhyoff also attended the National Geographic Information System Symposium cosponsored by the Forest Service in Atlanta, Georgia, in April 1986. He co-chaired a session there on the use of

geographic information systems interfaced to prediction models. Much of the technology discussed at this symposium was useful in evaluating and developing IPIAS. Virginia Tech purchased a Data General minicomputer for the purpose of supporting the development of IPIAS. Further, a Center for Quantitative Studies was developed at Virginia Tech to support research applications involving the integration of computer technologies such as IPIAS. The University invested approximately $250,000 in the creation of this Center.

During this time Dr. Daniel worked on the development and modification of the elk habitat model for the IPIAS installation on the Nezperze National Forest. The model was developed to merge with the IPIAS GIS data base and a working version of that model was available by the end of the year. Dr. Daniel also traveled to the Nezperze during July 1986 to interface and install the elk habitat model into the IPIAS system and participated in a week long work session there. Finally, Dr. Daniel participated in a week long work session in Tucson, Arizona with forest pest management/MAG and Fish and Wildlife Service personnel to develop ideas related to the integration of artificial intelligence concepts into IPIAS.

Fiscal Year 1987:

Under contract #28-C4-320 there were no specific objectives to be completed by September 30, 1987. However, a variety of tasks and endeavors were engaged in during this period of time in support of both previous efforts aimed at the development of IPIAS and also toward objectives to be completed by September 30, 1988.

Principle activities included participation in research and development, planning meetings, and review and evaluation of proposals for new work. Also, a pilot effort to assess the feasibility of using interactive laser disk technology for the creation of an image data base component to IPIAS was investigated. The image data base provides color video displays of forest areas representative of stand conditions similar to those projected by IPIAS forest growth and mortality simulation models. A third task was the development of a draft documentary and promotional video program highlighting IPIAS accomplishments and capabilities. Production of this program was carried out in conjunction with the

public television station at the University of Arizona. The video entitled "Advanced Technologies - New Tools for Old Challenges" was produced to assist in implementing a technology transfer plan for IPIAS. Finally, during FY 87 work continued on the development of a visual impact assessment module for IPIAS. All of these activities are discussed in detail in the following section entitled "Fiscal Year 87 Accomplishments".

Both Drs. Buhyoff and Daniel participated in meetings with members of the IPIAS steering committee, cooperating researchers, and Red River District management personnel. Site visits were made to the Red River Ranger District regarding field testing of IPIAS. In addition, an IPIAS technology transfer project was selected on the Deer Lodge National Forest, Basin - Thompson Project Area, Montana. Several visits were made to Basin-Thompson Project in Butte, Montana, for the purpose of transferring the prototype IPIAS concept from the Nezperze National Forest to the Deerlodge. Drs. Buhyoff and Daniel also represented the IPIAS development team at several national and regional scientific meetings and workshops, specifically demonstrating or presenting IPIAS capabilities and applications of each. Involvement in the initial planning of Resource Technology 88, the international symposium on advanced technology and natural resource management, consumed some of the effort for FY 87. A planning session held in Denver, Colorado, attended by both Drs. Buhyoff and Daniel for this purpose. Finally, a draft technology transfer plan was developed during this year which emphasized the general philosophy and approach for the dissemination of IPIAS technology was developed. It was noted that many of the components of technology transfer were accomplished during FY 87 or during the four previous years including the Basin-Thompson Project and the promotional video program. Presentation of this plan to the IPIAS Steering Committee during the steering committee meeting of December 1987 resulted in the acceptance of this plan by that committee.

<u>Fiscal Year 88</u>:

The bulk of the activity of this year was devoted to technology transfer through publication and participation on the executive planning committee for the Resource Technology 88 Symposium.

Contract requirements were dictated that the year be spent in overall coordination and technology transfer activities. Several meetings were attended by Drs. Buhyoff and Daniel for the purpose of organizing and planning the symposium. A major planning session was attended in Denver during the first week of December, 1987. Dr. Daniel was responsible for the program organization and Dr. Buhyoff was designated the responsibility for the publication of the proceedings. Both Drs. Buhyoff and Daniel attended the symposium held in Fort Collins in June, 1988. A majority of Dr. Daniels time during the spring of 1988 was devoted to Resource Technology 88 activities and a majority of Dr. Buhyoff-s time during July, August, and September of 1988 was devoted to editing and publication of the proceedings from the symposium.

Work also continued on the final refinement of the IPIAS (renamed) INFORMS video tape. The final version was produced based upon comments received at the steering committee meeting also held in December, 1987 in Denver. This final version of the technology transfer video was made available for distribution in the spring of 1988.

The following publications were prepared during FY 88. All were aimed at the idea of technology transfer of the IPIAS/INFORMS concept and working detail.

Hunter, D. O., Heasley, J. E., White, W. E., Daniel, T. C., and Buhyoff, G. J. 1988. Integrated Information Technology for Natural Resource Management. In: Proceedings of Resource Technology 88: International Symposium on Advanced Technology in Natural Resource Management. G. J. Buhyoff (Ed.). In Press.

Buhyoff, G. J. (Ed.) 1988. Proceedings of Resource Technology 88: International Symposium on Advanced Technology in Natural Resource Management. Fort Collins, Colorado. June 20-23, 1988. American Society for Photogrammetric Engineering and Remote Sensing, Falls Church, Virginia. In Press.

Buhyoff, G. J., White, W. B., Daniel, T. C., and Hunter, D. O. 1988. Integrated Computer Decision-Support for Forest Impact Assessment: A Conceptual Framework and Example. Artificial Intelligence Applications in Natural Resources Management. In Press.

FISCAL YEAR 1984 DETAIL

INTRODUCTION

The comprehensive objective of the work reflected in this report was to begin an assessment of user needs, user interfaces and potential models for an Integrated Pest Impact Assessment System (IPIAS). A brief overview of the IPIAS concept follows.

The development of the IPIAS system will be accomplished over a period of several years and will expand on and refine an existing system prototype. The current IPIAS system combines a set of previously developed socioeconomic impact prediction models into a "user friendly" interactive computer system. The goal of IPIAS is to provide forest planners and managers with an efficient and effective means for projecting the socioeconomic and biologic implications of alternative management actions. The system will focus upon the effects of forest changes associated with insect damage and insect control, but should be applicable to a much wider range of forest management problems. Estimates should be able to be made of a number of biological and socioeconomic effects of forest change, whether those changes were induced by insect infestation, silviculture, or harvest. Alternative forest conditions, resulting from specific treatments, insect damage, or normal growth and mortality should be described in terms of conventional forest mensuration measures. The user will provide forest characteristics, and IPIAS should produce

model-based estimates of social as well as timber and pulpwood benefits or losses expected for the described forest.

This system can be enhanced by integrating a forest stand data base, System 2000, and a Geographic Information System (GIS). The system should, for several time periods, take one initial stand, modify it by way of a growth simulator model, a pest outbreak model and a given prescription to yield a residual stand at each time period. These residual stands can then be evaluated for changes. These changes can be expressed as impacts. The linking of a computerized data base and a geographic information system should allow the user to quickly input specific stand data (e.g., System 2000) and spatially evaluate a resource question and then graphically and tabularly represent the final results.

The goal of the current 5 year project is, as noted above, to expand and refine this system, by incorporating a greater array of models which would predict impacts of mountain pine beetle infestations on timber, recreation, wildlife, watershed, slash/downed wood, range etc. as a result of stand changes. Also the current focus is on the Lodgepole Pine in Regions 1 and 6 of the U.S.F.S. However, information on impact models for other pests and forest types as well as stand projection systems is needed as well in order to evaluate the requirements and needs for IPIAS. The requirements of various forest staff specialists also need to be evaluated.

The initial task detailed here was to conduct an assessment of information needs related to such a system as well as a survey of existing forest stand projection and impact prediction models.

Specifically, this report presents the results of efforts aimed at accomplishing objectives 2, 3 and 4 as described in detail in Final Report to the U.S. Forest Service, Forest Pest Management/Methods Application Group on a Pest Impact Assessment Workshop, Milliken, Colorado, February 13-18, 1983, 32 pages.

This report is broken into two parts. Each of these parts describes the methods and results of work accomplished to meet the objectives noted above. Part I details efforts and results aimed primarily at objectives 3, above, (Identify existing forest stand, socioeconomic and mountain pine beetle models) and 4 (Identify Washington Office information needs). Part II describes the methods and results of work directed at achieving primarily objective 2 from above (Identify user interface needs). While the report is broken out by objectives it is done so for reading clarity only. The work effort, in fact, was integrated as the methods were somewhat recursive and often simultaneous.

Part I--OBJECTIVES

The particular objectives of this portion of the work to be completed during FY84 were:

1. Survey Washington Office staff about IPIAS information needs.

2. Conduct a literature search for forest stand and socioeconomic models.

3. Conduct a literature search for mountain pine beetle models.

4. Survey pest management and research groups for mountain pine beetle models currently being used or developed.

5. Report on existing forest stand and mountain pine beetle models, including types of data needed and types of output produced.

The effort to meet these objectives was aimed primarily at Regions 1 and 6 and more specifically at the Lodgepole pine type. Also the types of models which were researched included those in the following categories:

1. stand growth
2. debris (slash/downed wood)
3. insect and other pest
4. recreation use
5. visual quality
6. wildlife habitat
7. range
8. hydrologic
9. econometric
10. harvest scheduling

Part I--METHODS

During April 1984, five individuals in the Washington Office were visited and interviewed as to their perceptions of information needs concerning IPIAS. These individuals included James Stewart and Joseph Lewis of FPM; Robert Randall and Peter Ashton of the Policy Analysis section; and Robert Moulton of S&PF. In addition, these individuals provided names of others who could be contacted regarding models now in use or under development. As a result of the interviews in the Washington office a list of 35 other individuals was developed. These individuals were primarily

located either at the Region 1, 2 and 6 offices or were affiliated with the Rocky Mountain Forest and Range Experiment Station, the Pacific Northwest Forest and Range Experiment Station or the Intermountain Forest and Range Experiment Station. Each of these 35 individuals was contacted by mail or phone during April, 1984 and their responses were guaranteed to remain anonymous in an effort to solicit "real" feelings and attitudes about current modeling efforts and strategies. Specifically, each was surveyed on their knowledge and feelings about the types of impact or other models now in use or under testing or development. The survey (see FY84 Report) was entirely open-ended as the objective of this process was to uncover information and other leads on existing and future models. This information not only contributed to the results presented here, in Part I, but also to the design of the survey instrument aimed at Forest Service users of impact and other models (See Part II, this report). As a result of contacts with the respondents from the group of 35 described above, another 15 individuals from similar professional backgrounds were contacted by phone or mail in May, 1984 regarding their knowledge of models which fit any of the categories listed above in Part I--OBJECTIVES.

Also during this period Max R. Keetch, Systems Applications Specialist, S&PF, Fort Collins was contracted by FPM/MAG, Fort Collins to conduct a limited survey of socioeconomic models in use by the Forest Service which might prove integratable to IPIAS.

An information summary on each model which was determined to be potentially useful to an IPIAS formulation was entered into a data base management system for quick update and retrieval purposes.

Part I--RESULTS

Forty-four different models or extensions of models were identified and evaluated as being potentially applicable to IPIAS. Documentation was obtained for these models and where necessary, individuals who could clarify their use were contacted. Twenty-nine of the models were deemed as meeting the broad criteria of either generalized applicability to Regions 1 or 6, applicability to lodgepole pine, be useful in assessing impacts as the result of Mountain Pine Beetle infestations or in making predictions regarding the behavior of such infestations. Each of these models did not have to be applicable to all four criteria. These models are summarized (output from the computerized data base) in the section of this report indexed as DATA BASE. Note that some models are actually extensions or modifications of other models.

Nine other models were comprehensively evaluated but not included in the data base since their applicability to IPIAS was determined to be minimal or non-existent due to the regional nature of these models (i.e., not applicable to Regions 1 or 6). These included: INVEST III; MULTIPLOY; Budworm Evaluation Model; MTVEST; MAX2; RAMPREP; ECHO; SIMAC; SORAC. See Appendix B for more detail on INVEST III; MULTIPLOY; Budworm Evaluation Model and MTVEST. Descriptions of the other nonincluded models can be found in Leuschner (1984). In addition 32 more trend prediction, management simulation, hazard rating and spot growth models specific to Southern Pine Beetle were researched and assessed as to their potential applicability to IPIAS (Table 1). These models are summarized in "Southern Pine Beetle Predictions Handbook" Compiled by Garland N. Mason, USDA Forest Service, Integrated Pest Management RD&A Program, Pineville Louisiana, Revised June 1984. Again, these models are, however, not directly applicable to the development of an IPIAS in Regions 1 and 6 and are not included in the model data base presented on the previous pages. These models relate most directly to the contagion model aspect of IPIAS which is under separate development. However, some of the model types or concepts presented in this document may prove useful to the longer-term development of IPIAS

Finally, we admit that not every model in use was discovered. However, we feel that the most widely used models were evaluated. Models had to be documented and supported to be included in the following listings.

TABLE 1

Southern Pine Beetle Prediction

Models Evaluated(1)

<u>Trend Prediction Models</u>

SPB COMP

AERIAL GA

SOUTHEAST SURVEIL

SOUTHEAST PREDICT

NC SURVEIL

NC PREDICT

NC PIED SURVEIL

NC PIED PREDICT

GA SURVEIL

GA PREDICT

FRONSIM

DAMBUGS

<u>Management Simulation Models</u>

CLEMBEETLE

TABLE 1 continued

Hazard Rating Models

TFS GRID HAZARD

AR HAZARD

MS HAZARD A

MS HAZARD B

SADER HAZARD

P HAZARD GA

TX HAZARD

WEST GULF HAZARD

NF RISK

PIEDMONT RISK

MOUNTAIN RISK

WEST GULF PROB

COAST PROB

PIED PROB

Spot Growth Models

TAMBEETLE

ARKANSAS SPB

TFS SPOT GROWTH

E/A Ratio

---

(1) From Mason (1984; Revised June)

Part I-DISCUSSION

The models represented in the data base on the preceeding pages can be broken down into categories for which they make predictions (not necessarily impact) conduct efficiency analyses or perform simulations. The following breakdown is one way of assessing prevalence or absence of certain types of models. Note that some models appear under more than one category since they perform more than one type of prediction or analyses.

A. Growth and Yield

PROGNOSIS

TRAS

FREP/STEMS

TWIGS

TRIM

ECOSIM

GROW

DFSIM

INDIDS

TREES

R2GROW

RMYLD

B. <u>Insect/Pest</u>

PROGNOSIS extensions for: Western Spruce Budworm

Douglas Fir Tussock Moth

Dwarf Mistletoe

Mountain Pine Beetle

TREE LOSS FROM MOUNTAIN PINE BEETLE INFESTATIONS

INDIDS

LP-DM-VOL

C. <u>Economic Efficiency</u>

CHEAPO

FORESTRY INVESTMENT ANALYSIS

TRIM

DPDFSIM

LP-DM-VOL

D. <u>Harvest Scheduling</u>

TREES

PROGNOSIS extension: EVENT MONITOR

E. <u>Wildlife</u>

ECOSIM

PROGNOSIS extension: COVER

HABITAT SUITABILITY INDEX MODELS

F. HYDROLOGY

ECOSIM

WSDU*WATER

WATER BALANCE

G. Economic-Input/Output

IMPLAN

MICRO I/O

H. Debris

DEBMOD

QDEBRIS

I. Comprehensive Simulation

ECOSIM

Note that no range, recreation use or visual quality models are listed. While methods exist for developing such models, to the best of our knowledge there are no specific models either in use or under development. The wildlife category displays models which can aid wildlife impact predictions. However, one is specifically incorporated in the ECOSIM model itself and another (i.e., PROGNOSIS, COVER extension) makes projections of changes in shrubs and canopy which can potentially be used as input for more developed wildlife population models. The only comprehensive wildlife "impact" models are the Habitat Suitability Index (HSI) models developed by the Western Energy and Land Use Team (WELUT) of the U.S. Fish and Wildlife Service.

At this stage of the IPIAS program it is very difficult to further categorize the models which have been inventoried. While it is obvious that growth and yield models are different in their inputs/outputs from economic efficiency and other models, ultimate evaluations of any of these models and the resultant categorization of them can only be meaningful if we know the uses to which the models will be put. At the simplest level they are all prediction techniques. However, while we know they predict different things they do so in different ways. Some are simulations;others are optimization models. Also, they make predictions over different time frames, geographical areas and sometimes for different forest types. Further categorization for the sake of evaluation of these models for an IPIAS system will not prove very enlightening until the question of "what is the required geographic area and time frame for the predictions?" is answered.

The question of geographic scale of the predictions is critically involved in evaluating similarity of the models' functional capabilities for IPIAS. For example, TAMM and TRIM are aimed at RPA type assessments, primarily on a national scale. IMPLAN uses counties as the smallest projection unit. PROGNOSIS predictions can be accomplished for a single stand or a group of stands.

Related to the question of the area to be covered by the

impact predictions is the problem of deciding the use or time frame of the IPIAS predictions. For example, will IPIAS be used to plan suppression activities?; plan budget requests? plan field activities?; serve as input to FORPLAN?; estimate benefits of long term suppression programs?; be used to schedule short or long-term management regimes based upon maximizing some set of forest outputs?; or, serve only as additional information for making best professional judgements?

The Integrated Pest Management Program for Southern Pine Beetle has suggested a manner in which to categorize prediction models (Leuschner, 1979)

They suggest that all models be considered within a matrix defined by the interaction of time and area. This matrix as seen in Figure 1 provides not only a means of categorizing models but also a framework for making decisions about what an integrated impact system should include. IPIAS might include the entire matrix, some subset of contiguous cells or a single cell. Depending upon the answer to the comprehensiveness question, evaluation and categorization of existing models as to their usefulness to IPIAS may differ. Obviously the time frame of prediction will be related to the ultimate use of these predictions as discussed above.

If benefit/cost analysis is to be used as a decision criterion for assessing the impacts of control programs for pests, then those models which afford the opportunity to

integrate the components of such an analysis into their systems could be categorized together as potential components of IPIAS. If, on the other hand, impact tradeoffs are to be assessed in terms of minimizing some set of impact outputs (or conversely maximizing some set of constraints) then another different set of models can be categorized together. How precise to the impact predictions have to be? Is the prediction of an impact as being positive or negative good enough? If not then some models will not fit as components with other sin an integrated impact system.

Figure 1--Matrix of types of predictive techniques and model definitions appropriate to integrated pest impact assessment systems using time and areas of prediction as definitional criteria.

A R E A	IMMEDIATE	NEXT YEAR	MULTIPLE YEARS	ROTATION
NATIONAL				
REGION				
MANAGEMENT UNIT				
STAND				
SPOT				

T I M E

If IPIAS is to be an "impact" prediction system then impact needs to be defined and the component models need to predict these impacts. If we adopt a definition from Leuschner (1979) where he states that "...impact is the net effect of an insect upon the physical ability to produce goods and services desired by man...(where) impact has meaning only to the extent that it affects something which man desires", then it is clear that not all the models summarized in this report are impact models per se for insect damage or other forest changes. However, many of the models or systems can be used as components of a larger impact system such as IPIAS, since most have "impact" components in the loosest sense. That is, they predict changes in forest production (biological or economic) as the result of management action or inaction. Appendix B authored by Max Keetch also makes note of the distinction between impact models such as economic input-output models and economic efficiency models which output not changes in input values, but measures of production efficiency such as benefit/cost ratios and present net value. Most of the models presented here are also not specific to mountain pine beetle or other pests as forest change agent.

These questions arose directly out of the process of collecting and evaluating models for possible inclusion in the inventory and data base. The next effort should be aimed at answering the questions regarding the design of IPIAS and then reevaluating the models in this report for their effectiveness

in contributing to IPIAS. This task, in fact, meshes well with the development objectives (numbers 5 and 6 from Final Report to the U.S. Forest Service, Forest Pest Management/Methods Application Group on a Pest Impact Assessment Workshop, Milliken, Colorado, February 13-18, 1983, 32 pages) set for FY85 under cooperative agreement 28-C4-320 since it relates directly to the stated objectives.

LITERATURE CITED

Leuschner, W. A. 1979. Impact analysis, interpretation, and modeling. In. Waters, W. E. (ed) Current Topics in forest entomology; selected papers from the XVth international congress of entomology. USDA Forest Service General Technical Report WO-8. U.S. Government Printing Office, Washington, D.C., pp. 50-53.

Leuschner, W. A. 1984. Introduction to Forest Resource Management. John Wiley and Sons: New York. 298pp.

Mason, G. N. 1984 (Revised June). Southern pine beetle predictions handbook. USDA Forest Service, Integrated Pest Management RD&A Program, Southern Region, Atlanta, GA.

PART II--OBJECTIVES

The specific objectives of this portion of the work to be completed during FY 84 were:

1. Identify potential users groups of IPIAS

2. Identify information currently used by these groups and how it is used.

3. Identify additional information user groups would like to have.

4. Describe outputs a pest impact assessment system should produce to meet the above needs.

Part II--METHODS

Based upon the partial results described in Part I which were available in late May, 1984, a survey was designed to assess the user needs and interface requirements. This questionnaire was sent to 255 individuals in Regions 1 and 6. Each Regional Office and each Forest District were sent copies of the questionnaire. Copies were sent to specialists in all areas and included timber management, recreation, hydrology, planning, wildlife, silviculture and pest management. The intent of the questionnaire was to not

only assess user interface needs but also to uncover other models which were not discovered by the methods of Part I of this report.

PART II - RESULTS

A total of 62 completed survey responses were returned. In a number of cases, one respondent represented the model use/needs of several individuals; i.e., survey recipients tended to pass the questionnaire on to their "resident model user". We discovered that some individuals who had been mailed surveys in Region 6 did not return them since they thought that this questionnaire was in some way related to a survey on use of growth and yield models previously conducted by the Region. Therefore, in an effort to augment the information from Region 6, we asked that someone in the Regional Office fill out a questionnaire which would comprehensively summarize model use for the entire Region. Two people from the Region 6 office collaborated in this endeavor and their responses are noted and treated separately in the following tables and discussion (denoted by VI). These responses are labelled "Regional Experts". While the distribution list for the survey was comprehensive, there was no way to assure a complete return. Thus, the "representativeness" of the respondents is to some extent unknown, and there may be models and/or users in the targeted regions that were not captured by this survey.

RESPONDENTS. The geographic distribution of survey respondents indicated good coverage of Regions 1 and 6. District, Forest and Regional levels were all represented. Table 1 presents the distribution of respondents by indicated specialty. Not surprisingly, the large majority of respondents were silvicultural specialists. The low response rate from other forest specialists is consistent with the lack of available models for wildlife, recreation, or aesthetics, that was reported in Part I.

MODELS USED. Table 2 presents the models identified by the survey respondents and the number of respondents indicating some use of each. Models with 0 users indicated they were specifically listed in the survey, but no respondents reported using them. Clearly, PROGNOSIS was the most frequently reported model, with only DFSIM having a lower but still appreciable number of users. The greatest majority of models reported were used by only one or two respondents and in several cases models may only be used by the developer. Indeed, several models reported here were not found in the Part I survey, and are not widely used or not comprehensively supported. Detailed analysis of model use, therefore, was restricted to PROGNOSIS AND DFSIM.

Table 3 presents the distribution of reported annual frequency of use for PROGNOSIS and DFSIM. For both models, the

majority of respondents indicated use frequencies of 10 or less per year. The Region 6 experts estimated equal frequencies of use for the two models. Individual respondent reports indicate considerably more frequent use of PROGNOSIS. This is due, in most part, to the fact that across the two Regions (1 and 6) there is less total area in Douglas Fir (e.g., DFSIM useage) than there is in forest area for which PROGNOSIS could be used.

TABLE 1

RESPONDENT JOB DESCRIPTION, TITLE OR SPECIALTY

Respondent	frequency
Silviculturalist/Silvicultural Administration/ Silvicultural Assistant	50
Timber Management/Planning Forester	3
Ranger/Ranger Assistant/Timber Assistant	3
Forester-Reforestation	2
Economist, Forest	1
Fire Management	1
Planning Team Coordinator	1
Plant Ecologist	1
TOTAL	62

TABLE 2
FREQUENCY OF MODEL USE

Name of Model	# of Users	Name of Model	# of Users
PROGNOSIS	43 (VI)	DFIT	1
DFSIM	13 (VI)	IRPM	1
GROW	4	PERSPECTIVE PLOT	1
INDIDS	4	SEDMOD	1
RMYLD	4	TAMM	1
IMPLAN	3	TREES	1
MGYLD (5&6)	3	W. HEMLOCK BY KEN WILEY	1
DEBMOD (or DEBMOD 6)	3	WILDLIFE HABITAT EFFECTIVENESS	1
BEHAVE (part of DEBMOD)	2		
GROWTH & YIELD IV	2	TRAS	0
HAZARD (part of DEBMOD)	2	TRIM	0
LPSIM	2 (VI)	ECOSIM	0
PIERATT	2	RAMPREP	0
Q DEBRIS	2	FREP	0
WATER BALANCE	2		
"OTHER WHOLE STAND"	2		

TABLE 3

Question #2, "Indicate...how frequently (i.e., number of times per year) you use or access the models or systems...in current use"

	PROGNOSIS	DFSIM & DP-DFSIM
REGION 6 EXPERTS :	1500x	1500x
INDIVIDUAL RESPONDENTS:	1-5x, N=15	1-5x, N= 3
	6-10x, N=10	6-10x, N= 4
	11-15x, N= 4	11-15x, N= 1
	16-20x, N= 2	16-20x, N= 1
	21-40x, N= 3	21-40x, N= 2
	41-60x, N= 5	41-60x, N= 0
	61-80x, N= 1	61-80x, N= 0
	81-150x, N= 2	81-150x, N= 1
	151-220x, N= 2	151-220x, N= 0
	500x, N= 1	500x, N= 0

TABLE 4

Question #19, "If you currently use PROGNOSIS which, if any, of the extensions do you use (e.g., mountain pine beetle, COVER: Shrubs and Canopy, regeneration establishment, event monitor, parallel processing, etc.)?"

Response Category	frequency
MPB	16(VI)
COVER	15(VI)
REM	12(VI)
CHEAPO	8(VI)
WESTERN SPRUCE BUDWORM	3(VI)
D. FIR TUSSOCK MOTH	2(VI)
EVENT MONITOR	2(VI)
PARALLEL PROCESSING	2
SHRUBS	1
STAND AGGREGATIONS	1
TOTAL	62

Not using PROGNOSIS or not using extensions or no reply	22
Extensions not accurate for this region's conditions....	4

Only two respondents specifically indicated use of PROGNOSIS extensions in response to the first part of the survey (i.e., the table of models used). Table 4, however, shows that when specifically asked about the use of extensions (Question 19), MPB, COVER, REM, and CHEAPO were all indicated by a substantial number of respondents. The Region 6 experts also reported use of these and other extensions. Some individual respondents used this question to report that "extensions were not accurate" for their area or forest type.

Consistent with the reported pattern of model use, the indicated destination for model outputs (question 14) is principally timber planning and management. Table 5 shows that PROGNOSIS output is used most by timber and planning staffs, with considerable use by pest management and wildlife also indicated. DFSIM is principally used by timber staff.

Responses to Question 13 (see appendix E) indicated that model output is not typically used in a direct numerical form, but rather serves as a basis or guide for professional judgement. Some of the individual respondents did report that PROGNOSIS quantitative output is used directly. When queried about the actual influence that model results had on planning and management (Question 12), the Region 6 experts felt that both PROGNOSIS and DFSIM results had a great effect, while individual respondents were split almost equally among great, moderate, and slight for PROGNOSIS, and predominantly responded moderate for DFSIM.

TABLE 5

Question #14 "Who are the users of the output from the models in current use?"

	PROGNOSIS			DFSIM & DP-DFSIM		
INDIVIDUAL RESPONDENTS:	Timber	N=43	(VI)	Timber	N=13	(VI)
	Planning	N=30	(VI)	Planning	N=5	(VI)
	Pest Mgt.	N=18	(VI)	Pest Mgt.	N=0	
	Wildlife	N=13	(VI)	Wildlife	N=3	(VI)
	Hydrology	N=6		Hydrology	N=0	
	Landscape	N=4		Landscape	N=0	
	Engineer.	N=2		Engineer.	N=2	
	Recreation	N=1	(VI)	Recreation	N=0	(VI)
	Range	N=1		Range	N=0	
	Other	N=3		Other	N=1	

MODEL INTEGRATION. Question 3, 4, and 17 addressed the extent to which models are linked or integrated with data bases, geographic information systems (GIS) or other models. Responses to questions 3 and 4 indicate some linkage between PROGNOSIS and the forest stand inventory or System 2000 timber data base. DFSIM was reported as not linked in any way. Neither PROGNOSIS nor DFSIM are linked with any consistency to a GIS. Aside from linkages between PROGNOSIS and its extensions (e.g., CHEAPO), there appears to be little or no model-to-model linkages in use by the survey respondents (Question 17). There was some indication (6 respondents) of a linkage between FORPLAN and PROGNOSIS, but it is not clear whether this is a hard or soft linkage.

RANGE OF APPLICABILITY. Responses to questions 7, 8, and 15 indicated that both PROGNOSIS and DFSIM are best applied to even-aged softwood stands. DFSIM is, in fact, restricted to newly established, even-aged Douglas Fir stands. PROGNOSIS was viewed as particularly useful for Douglas Fir, Pondersosa Pine, and Lodgepole Pine applications. PROGNOSIS was also viewed as being useful in making predictions of impacts of Mountain Pine Beetle damage given the availablity of the MPB extension to PROGNOSIS.

COSTS AND BENEFITS. Individual respondents were evenly divided in their assessments of the ease of use of both PROGNOSIS and DFSIM (Question 5). Half judged the models easy

to use, and half indicated that they were moderately difficult to utilize. The Region 6 experts, however, judged PROGNOSIS moderately difficult and DFSIM easy to use. Meeting data requirements for both models (Question 6) was judged as moderately difficult for both models, although the Region 6 experts reported that data requirements posed no difficulties for either model. Access to both models (Question 11) was judged generally to be easy, although a significant number of respondents found access to PROGNOSIS moderately difficult. Specifically, these individuals cited computer time availability and model adjustment requirements as the most prevalent problems.

Cost estimates (Question 9) in both man-hours and computer time are shown in Table 6. On both counts, costs for both models were judged as being moderately low. The Region 6 experts indicated that DFSIM was, in their judgement, a little less costly than PROGNOSIS. Respondents to Question 10 indicated virtually unanimous agreement that the costs of using both PROGNOSIS and DFSIM were outweighed by the accrued benefits of running them.

CHANGES AND ADDITIONS. Questions 18 and 20 addressed the need for and nature of changes in models now in use. Most respondents indicated that changes would be needed to meet future modeling requirements (Question 18). Several types of needed changes and improvements were cited in response to Questions 18 and 20. The most frequently indicated desireable

changes were improvements in the user interface to models and included: better hardware and software links to data bases and GIS's; reduced redundancy in data/parameter entry; greater attention to interactive modes of operation; more graphic output; and increased overall user-friendliness. The next most desired ammendment to the models was increased accuracy in the growth, mortality and yield predictions. In this context, a number of respondents called for easier and better means of calibrating models for local site conditions. At the same time, a wider range of applicability was also desired, including extensions to more localities, different forest compositions (especially mixed age and species) and special applications such as to very young or very old stands,

TABLE 6

Question #9, "Please rate the costs (this refers to both time and monetary and should include man-hours and computer time) of using each of these models."

	PROGNOSIS	DFSIM & DP-DFSIM
INDIVIDUAL RESPONDENTS:	High cost man-hours, N=3	High cost man-hours, N=0
	Moderate cost man-hours, N=15(VI)	Moderate cost man-hours, N=7
	Low cost man-hours, N=23	Low cost man-hours, N=6 (VI)
	High cost computer time, N=2	High cost computer time, N=0
	Medium cost computer time, N=17(VI)	Medium cost computer time, N=4
	Low cost computer time, N=24	Low cost computer time, N=9 (VI)

overstocking effects, and newly planted stands.

Respondents were aware that changes and improvements are underway for a number of existing models (Question 16). Most were aware that PROGNOSIS is "constantly being updated" and that new forms, subroutines and extensions are in various stages of development.

PEST IMPACTS. Question 21 specifically asked what new models are desired for predicting pest, or specifically Mountain Pine Beetle, impacts. The largest number of responses cited the need for models to deal with a variety of pest/disease problems, including root diseases, mistletoe and a long list of assorted other insects and fungi. Models to deal with "other forest resources" were also cited, especially wildlife and wildlife habitat. Economic, hydrologic, recreation, and visual/scenic models were each cited by two respondents. The need for extension of models to other host-types was also noted in responses to this question.

THE IDEAL SYSTEM. In Question 22 respondents were asked to indicate the components they would like to have in an integrated pest impact assessment system. Most agreed that the example components listed in the question (timber supply, wildlife, stand projection, contagion, and recreation) would be useful. In addition, components to address economic, hydrologic, visual/scenic, and fire effects were also listed.

Here, and in several other places in the survey, a few respondents expressed skepticism toward models for "subjective values like scenic value or recreation. Other comments suggest a skepticism about models in general, "I think I can guess outbreak occurrence about as close as a model might". In at least one case, it was felt that model developments may be too late, "We do not need MPB (models) since all our lodge pole pine are already dead."

PART II -- DISCUSSION

While every effort was made to survey all models and model users in Region 1 and 6, there is guarentee that every model or model use problem has been identified. In combination, however, the direct interviews with knowledgeable individuals at national, regional and forest levels as well as within the Forest Experiment Stations (Part I), the survey of model developers and expert users in both target regions, and the responses to the mailed survey provide a consistent and comprehensive profile of model use in forest management and planning. A number of "models" that were reported (or even rumored) to be in use were investigated and found to be either only "guidelines", severely restricted growth and yield equations or were not systematically implemented and/or documented for general use. These were not included in this

analysis, which focused upon documented models which were, at least in principle, available for general use and which had been implemented on a computer system of some nature.

It is very clear from this survey that the principal use of models in the target regions is for timber management. Forest silvicultural specialists far outnumber all other model users and "growth and yield" models are the most available, most used, and most sophisticated of the models identified by the survey. Indeed, the use of models for wildlife, recreation, scenic quality, range and water appears to be negligible or nonexistent. While some successful models have been developed in these areas (e.g., Buhyoff et al. 1982, Schroeder and Daniel 1981, Shamburger 1981, Walsh et al. 1981), they are apparently not well known in these regions, and are currently not in use. Even in forest economics, where quantitative analysis and computer modeling has a more extensive history, little use of models was reported. Pest management reported substantial model use, but this was principally in very close relation to timber management activities.

PROGNOSIS and , to a much lesser extent, DFSIM were the dominant models used in Regions 1 and 6. Users of PROGNOSIS outnumbered the users of all other models by a very wide margin. Again, this is due to the fact that PROGNOSIS has wide species and geographic application. User confidence in PROGNOSIS was generally high, though many users cited the need

for improving the accuracy by better calibration to local conditions. At the same time, the relatively wide range of application was recognized as a strength, and there were several calls for an even greater range of applications. In this context, the need for a less demanding, more user friendly interface to PROGNOSIS, a concern cited by a number of users, becomes especially critical. The challenge to PROGNOSIS and other models for this user group, is to provide the desired generality <u>and</u> local accuracy without introducing excessive input data requirements or mandating high computer sophistication on the part of the user.

Integration between models and data bases appears to be at a very low level. There is some linkage between PROGNOSIS and one or another version of the standard forest inventory data bases. Linkages to geographic information systems are not presently available except where users have invented their own systems as such. Linkages among models in use is essentially nonexistent except for the PROGNOSIS extension models which are directly tied to the main PROGNOSIS growth and yield module. The most comprehensive effort at model linkage is represented by ECOSIM, but this system is not generally available and essentially no use was reported in Regions 1 and 6. Once again, respondents requests for improved user interface are relevant. Effective integration of models and data bases could reduce the need for repetitive and redundant data entry, parameter specifications and input/output control formats.

Most users felt that the costs of model use were reasonable, and virtually all agreed that costs were outweighed by benefits. Indications are that model projections are substantially influencial in forest planning and management, and they may be even more so in the future. In this context, the essential lack and non-use of systematic models for representing impacts on wildlife, scenic quality, recreation, and other social and socioeconomic concerns necessarily implies rather low potential for these "other forest resources" to influence forest planning and management. Social impact models, or at least methods for developing such models, are available. Thus this imbalance, which may be inconsistent with a number of public land managemnet policies and regulations, need not continue. Survey results indicate, however, that there is little knowledge of the existing social impact models, little acknowledgement of the _need_ for such models (except perhaps for wildlife), and in few instances outright anatagonism toward the concept of modeling scenic or recreation values.

This survey of model use provides a basis for characterizing contemporary forest planning and management, at least as represented by Regions 1 and 6. For timber management and related pest management concerns the use of computer-implemented models of forest growth and mortality is intensive, wide spread, and increasing. The influence of model projections on the formulation and selection of forest

management alternatives is currently substantial, and promises to increase, especially given the frowing availability of the computer hardware that is required for efficient use of these models. This scenario provides substantial impetus for the parallel development of systematic, computer implemented models to represent other forest management concerns. In this regard, Forest Pest Management has set an important example by developing models of insect infestation and damage that are intimately interrelated with the dominant forest growth and yield models. The PROGNOSIS extensions, MPB, Western Spruce Budworm, Douglas Fir Tussock Moth, and the MPB contagion model under development indicate a potentially fruitful approach to be followed by other resource specialists.

The survey results also have important implications for the further development of the Integrated Pest Impact Assessment System. First, there is a recognized need for systematic impact assessment models to support forest planning and management. Models that have a reasonably wide range of applicability, that provide for accurate projections across stand types and site types, and that are easy for users to access and implement will have a large and eager clientele. Achieving such a system of models presents a considerable challenge, but significant progress is a already represented by such efforts as ECOSIM and the PROGNOSIS family of models. However, it will still be necessary to develop prediction models for recreation, esthetics and other socioeconomic concerns if forest manageement and planning efforts are to be

aided in their attempts to meet the requirements of RPA, NEPA and the Multiple Use and Sustained Yield Act.

FISCAL YEAR 1985 DETAIL

INTRODUCTION

The development of an expanded Integrated Pest Impact Assessment System (IPIAS) is to be accomplished over a period of several years (Daniel et al, 1983). The goal of IPIAS is to provide forest planners and managers with an efficient and effective means for projecting the socioeconomic and biologic implications of alternative management actions resulting from forest pest outbreaks. The system will not only focus upon the effects of forest changes associated with pest damage and control, but will also be applicable to a much wider range of forest management problems (e.g., anything which causes stand modification).

The first phase of the development of an expanded Integrated Pest Impact Assessment System (IPIAS), an inventory of forest stand, pest and other forest resources impact models was conducted during FY 84. These models were evaluated for their applicability to the IPIAS concept under which models would be linked to provide management information about predicted impacts of forest pests. In unison with this inventory, a survey was conducted of potential users of IPIAS. This survey solicited opinions about current impact model use as well as future model needs. Results of these efforts indicate both a need for IPIAS and the existence of potentially useful base of models for formulating IPIAS (Buhyoff and Daniel, 1984).

This document reports the results of continued assessment efforts which were tasked for FY 85 under Cooperative Agreement 28-C4-320. Specifically, the following were accomplished:

1) Evaluate and compare existing models with respect to their inputs, outputs and relation to user needs.
2) Survey data requirements for models which will be recommended for IPIAS use.
3) Recommend models which could serve as the basis of a "core" IPIAS and specify tasks which would bear upon refining exisiting model useage by IPIAS or developing new ones.

4) Identify data required by the "core" IPIAS models but not available.

5) Select a demonstration (pilot) project Forest for the IPIAS concept.

Objectives 1 and 2 of this report were met, in large part, by the Buhyoff and Daniel FY 84 progress report. The work aimed at these two objectives was primarily conducted and reported in 1984, since it was most efficient (although not required) to perform a comparison of model outputs and user needs at the same time the inventory of these two was completed. Although the substantive findings related to objectives 1 and 2 above can be found in the FY 84 report, further work related to these objectives was performed during FY 85. Therefore, PART I of this report provides an expanded summary of the FY 84 report but includes new information and ammendments to that report which resulted from tasks accomplished during FY 85. PART II discusses findings and recommendations related to objectives 3, 4 and 5 above.

PART I
Model Inventory and Data Requirements Assessment

A comprehensive evaluation was conducted of currently available pest impact and other forest prediction models which might be candidates for IPIAS application in targeted demonstration areas (USFS Regions One and Six). The primary inventory was conducted during FY 84 but further information gathering was performed during FY 85. Models were identified and evaluative criteria developed based on intensive personal interviews with individuals in the Washington Office, in the Forest Research Stations, and in the Region One and Six staffs. A total of fifty-five individuals, all very familiar with the development and use of models for forest management and planning, were contacted in this model evaluation phase. As a result, forty-eight separate models or model extensions were identified and evaluated for their potential usefulness to IPIAS and were entered into a computer data base management system for quick reference and update. Documentation was obtained

for these models and where necessary, individuals who could clarify model use were contacted. Thirty-two of the models were deemed as meeting the broad criteria of either generalized applicability to Regions 1 or 6 or applicability to lodgepole pine. These models also had to be useful in assessing impacts as the result of Mountain Pine Beetle infestations or in making predictions regarding the impacts resulting from infestation management. The models did not have to be applicable to all four criteria. This was not merely a literature search since the total effort described here included analysis of the models as to their applicability to IPIAS as well as an evaluation of each model's potential interfaceability to a broader network of impact models as required by IPIAS. Each of the models were evaluated for application region, stand and species type; input data requirements; output data requirements; limitations and constraints; extensions and modifications and indications of validity testing.

The remainder of the forty-eight models were also comprehensively evaluated but not included in the data base since their applicability to IPIAS was determined to be minimal or non-existent due to their applicability to non-target regions of these models (i.e., not applicable to Regions 1 or 6). These included: INVEST III; MULTIPLOY; Budworm Evaluation Model; MTVEST; MAX2; RAMPREP; ECHO; SIMAC; and SORAC. In addition to the forty-eight models, thirty-two other trend prediction, management simulation, hazard rating and spot growth models specific to Southern Pine Beetle were researched and assessed as to their potential applicability to IPIAS. These models are summarized in Mason (1984). Again, these models were, however, not directly applicable to the development of IPIAS in Regions 1 and 6. During this model identification phase, several other quantitative impact models were uncovered. However, these models were discovered to be "only guidelines", "under development", "not-tested", "currently being debugged", "not widely applicable", or in some cases, only rumored and did not actually exist. The final thirty-two models which were selected as being potentially useable by IPIAS can be found in the FY85 progress report which includes updated information to the FY 84 model data base as well as additional models. This data base includes information on model outputs as well as data input requirements (objectives 1 and 2, above).

It is particularly noteworthy that no range, recreation use or visual quality models are listed. Current approaches to the assessment of impacts on "other" forest resources such as social impacts tend to be more qualitative than quantitative and to rely on expert judgment rather than explicit analytical systems despite the fact that the technology exists to formulate such models.

The wildlife category displays models which can aid wildlife impact predictions. However, one is specifically incorporated in the ECOSIM model itself and another (i.e., PROGNOSIS, COVER extension) makes projections of changes in shrubs and canopy which can potentially be used as input for more specific wildlife population models. A single quantitative model for the prediction of elk movement was found for the target regions. Also, a comprehensive set of wildlife "impact" models developed by the Western Energy and Land Use Team (WELUT) of the U.S. Fish and Wildlife Service were also identified. These models (Habitat Suitability Index (HSI) models) project impacts on wildlife and fisheries species by predicting habitat suitability (as a 0-1 index) resulting from changes in that habitat. These HSI models appear to be of the type suitable for IPIAS. From our research it seems that "rules of thumb" are more prevalent than mathematical formulations for making predictions of changes in wildlife levels. For example, Thomas (1979) details many descriptions of habitat types which support various bird and wildlife species.

Use of Models in IPIAS

IPIAS should not be a single set of models to be used in all locations. Rather, IPIAS should be defined as a framework for a computer assisted forest management information system that can link together (1) biological (including forest growth and mortality, yield, and pest effects); (2) economic (stumpage values, management costs, and local and regional economic effects); and (3) social impact (recreation, scenic beauty, and wildlife) components. IPIAS will provide information assimilation and presentation rather than optimization. It is not, by itself, a decisionmaking system. Because of its modular design and its use of forest characteristics as a basic input to all impact modeling IPIAS can be used to address a wide range of forest management problems for a specific application area (e.g.,

a major drainage). Thus the comprehensive model inventory and evaluation presented here and in Buhyoff and Daniel (1984) provides information necessary for determining what components can be "pulled off the shelf" to be linked into IPIAS for a particular geographic forest management unit application.

At this stage of IPIAS development program it is very difficult to further define the exact linkages and use of the models in IPIAS. While it is obvious that growth and yield models are different in their inputs/outputs from economic efficiency and other models, ultimate use of any of these models and the resultant use of them by IPIAS can only be meaningful given specific user needs. At the simplest level they are all prediction techniques. However, while we know they predict different things they do so in different ways. Some of the models listed in the FY84 and FY85 progress reports are simulations; other are optimization models. Also, they make predictions over different time frames, geographical areas and for different stand types. Since the primary intent of IPIAS is to be a management information rather than a management decision system, the basic IPIAS framework will not ordinarily provide linkages to <u>optimization</u> models but only to <u>impact</u> models. However, should a set of users wish optimization model linkages, these can be defined and constructed.

The question of geographic scale of the predictions is also critically involved in evaluating similarity of different models' functional capabilities for IPIAS. For example, TAMM and TRIM are aimed at RPA type assessments, primarily on a national scale. IMPLAN uses counties as the smallest projection unit. PROGNOSIS predictions can be accomplished for a single stand or a group of stands. Thus, it should be possible to construct IPIAS packages of different area scales.

Related to the question of the area scale for impact predictions is the question of deciding the use of or time frame for IPIAS predictions. IPIAS will probably be used to plan or schedule, for example, suppression activities; budget requests; field activities; and, short or long-term management regimes. Uses, then, define the time scale of the total scope of IPIAS.

The Integrated Pest Management Program for Southern Pine Beetle has suggested a manner in which to categorize prediction models (Leuschner, 1979; Mason, 1984). They suggest that all models be considered within a matrix defined by the interaction of time and area. This conclusion was reached as a result of the current FY 85 activities. Obviously the time frame of prediction is related to the ultimate use of these predictions in a specific application area (e.g., stand level suppression activities versus watershed silvicultural prescriptions).

If benefit/cost analyses are required by a particular subset of users as decision critera for assessing the impacts of control program for pests, then those models which afford the opportunity to integrate their outputs into benefit/cost analyses could be linked together as potential components of a particular operationalization of IPIAS. If, on the other hand, only general impact tradeoffs are to be assessed then another, different set of models can be linked together.

The process by which these models can be accessed by users and linked together in order to solve pest impact problems across a broad range of geographic and time requirements is problematic. However, the Southern Pine Beetle Decision Support System (SPBSS) is an example of one way to accomplish this task (Rykiel, E. J. et al., 1984). The Decision Support System (DSS) is an interactive computer program which acts as an operating "shell" or executive program to manage a library of models and information about them. This system can aid the user define the nature of his pest problem and can recommend predictive models to use in the problem solution (subprogram called FERRET). Further, it can automatically link appropriate models and coordinate the execution of them to provide comprehensive impact output. This DSS, or one similar to it, may well provide the basic operating framework for IPIAS.

Current Model Use and Needs

A survey was designed to assess user characteristics, the need for pest impact models and user interface requirements (e.g. objective 1, above). This questionnaire was sent to 255 individuals in Regions 1 and 6. Each Regional Office and each Forest District were sent copies of the questionnaire. They were also sent to specialists in all areas and included timber management, recreation, hydrology, planning, wildlife, silviculture and pest management. The intent of the questionnaire was to not only assess user interface needs, but also to uncover other models which were not discovered during the model inventory phase. 1/

A total of 62 completed survey responses were returned. In a number of cases, one respondent represented the model use/needs of several individuals; i.e., survey recipients tended to pass the questionnaire on to their "resident model user". While the distribtuion list for the survey was comprehensive, there was no way to assure a complete return. Thus, the "representativeness" of the respondents is to some extent unknown, and there may be models and/or users in the targeted regions that were not captured by this survey.

The geographic distribution of survey respondents indicated good coverage of Regions 1 and 6. District, Forest and Regional levels were all represented. Not surprisingly, the large majority of respondents were silvicultural specialists. The low response rate from other forest specialists in consistent with the lack of available models for wildlife, recreation, or aesthetics, that was reported above.

While every effort was made to survey all models and model users in region 1 and 6, there is no guarantee that every model or model use problem was identified. In combination, however, the direct interviews with knowledgeable individuals at national, regional and forest levels as well as within the

----

1/ Detailed results of this user survey of model use and needs can be found in Buhyoff, G. J. and Daniel T. C., 1984. Integrated Pest Impact Assessment System: Development and Operations Coordination - FY 84 -Progress Report. Prediction Model Survey and User Needs assessment. Submitted to U.S.F.S., FPM/MAG, Fort Collins, Colorado.

Forest Experiment stations, the survey of model developers and expert users in both target regions, and the responses to the mailed survey provide a consistent and comprehensive profile of model use in forest management and planning. Again, a number of the "models" that were reported (or even rumored) to be in use were investigated and found to be, for example, either only "guidelines", not widely applicable, or not documented for general use. These were not included in the analysis, which focused upon documented models which were, at least in principle, available for general use and which had been implemented. It was very clear from this survey that the principal use of models in the target regions is for timber management. Forest silvicultural specialists far outnumber all other model users and "growth and yield" models are the most available, most used, and most sophisticated of the models identified by the survey. Indeed, as noted before, the use of models for wildlife, recreation, scenic quality, range and water appears to be negligible or nonexistent. While some successful models have been developed in these areas (e.g., Buhyoff et al. 1982, Schroeder and Daniel 1981), they are apparently not well known in these regions, and are currently not in use. Even in forest economics, where quantitative analysis and computer modeling has a more extensive history, little use of models was reported. Pest management reported substantial impact model use, but this was principally in very close relation to timber management activities.

PROGNOSIS and, to a much lesser extent, DFSIM, both growth and yield simulators, were the dominant models used in Regions 1 and 6. Users of PROGNOSIS outnumbered the users of all other models by a very wide margin. Again, this is due to the fact that PROGNOSIS has wide species and geographic application. User confidence in PROGNOSIS was generally high, though many users cited the need for improving the accuracy by better calibration to local conditions. At the same time, the relatively wide range of application was recognized as a strength, and there were several calls for an even greater range of application. In this context, the need for a less demanding, more user friendly interface to PROGNOSIS, a concern cited by a number of users, becomes especially critical. The challenge to PROGNOSIS and other models for this user group, is to provide the desired generality

<u>and</u> local accuracy without introducing excessive input data requirements or mandating high computer sophistication on the part of the user.

Integration between models and existing data bases appears to be at a very low level although users saw this integration as a primary need. There are some linkages between PROGNOSIS and one or another version of the standard forest inventory data bases. Linkages to geographic information systems are not presently available except where users have invented their own systems as such. Linkages among models in use is essentially nonexistent except for the PROGNOSIS extension models which are directly tied to the main PROGNOSIS growth and yield module. Once again, respondents requests for improved user interface are relevant. Effective integration of models and data bases, particularly via a geographic information system (GIS), could reduce the need for repetitive and redundant data entry, parameter specifications and input/output control formats.

Indications are that model projections are substantially influential in forest planning and management, and they may be even more so in the future. In this context, the essential lack and non-use of systematic models for representing impacts on wildlife, scenic quality, recreation, and other social and socioeconomic concerns necessarily implies rather low potential for these "other forest resources" to influence forest planning and management. Social impact models, or at least methods for developing such models, are available. Thus, this imbalance, which may be inconsistent with a number of public land management policies and regulations, need not continue. Survey results indicate, however, that there is little knowledge of the existing social impact models or scenic impact models.

This survey of model use provides a basis for characterizing contemporary forest planning and management, at least as represented by Regions 1 and 6. For timber management and related pest management concerns the use of computer-implemented models of forest growth and mortality is intensive, wide spread, and increasing. The influence of model projections on the formulation and selection of forest management alternatives is currently substantial, and promises to increase, especially given the growing availability of the computer hardware that is required for efficient use of these models. This scenario provides substantial impetus for the parallel development of systematic,

computer implemented models to represent other forest management concerns. In this regard, Forest Pest Management has set an important example by developing models of insect infestation and damage that are intimately interrelated with the dominant forest growth and yield models. The PROGNOSIS extensions, MPB, Western Spruce Budworm, Douglas Fir Tussock Moth, and the MPB contagion model under development indicate a potentially fruitful approach to be followed by other resource specialists.

PART II

The results of the model inventory and assessment and the user survey have important implications for the further development of the Integrated Pest Impact Assessment System (objectives 3 and 4).

1) There is a recognized need by potential users for systematic impact assessment models to support forest planning and management. Models that have a reasonably wide range of applicability, that provide for accurate projections across stand types and site types, and that are easy for users to access and implement will have a large and eager clientele.

2) IPIAS models should be chosen (i.e. for a particular application area) according to the needs of the specific Forest or District to which an application is designed. These models should include those that may be used for immediate impact prediction from suppression or other management activities as well as those which will assess impacts of management activities through the rotation age or cutting cycle of a particular stand.

3) The most immediate needs for IPIAS seem to be at the stand level. IPIAS impact assessments should also be able to be aggregated across stands to provide larger area impact predictions.

4) There is a need to link IPIAS impact models to a common data base(s) which has/have the capability of being easily ammended so as to provide all input information for the models selected for a particular IPIAS application.

5) The IPIAS models and input data base should be able to be "run" on on-site computer systems since one of the most important user interface needs is that such a system not require mainframe access and thus be constrained by communications links.

6) The greatest user interface problem will relate to the ease of use and transparancy of operation of IPIAS. That is, users should not be required to learn command languages nor should they need to actually be involved in the establishment of model linkages. Some sort of Decsion Support System with an Expert System overlay would be an ideal operating environment for IPIAS.

7) The most critical elements of the IPIAS "core" configuration should be an input data base such as a geographic information system, a growth simulator which will "drive" other impact models, and a contagion model to serve as the primary "impact producer". Specific impact models (e.g., watershed, fish and wildlife habitat, wildlife migration, visual, recreation, fire behavior, etc.) should be selected and/or developed for a specific application area since the needs of Forests (and even Districts) will differ. a.) A major work effort should be aimed, then, at the continued development of a GIS linkage to IPIAS. In fact, many of the data needs by forest managers seem not to require prediction models per se, but rather data in the form of "overlays". That is there is a need to able to define forest areas which share common attributes such as soils, insect damage, topogaphic characteristics and so on. A GIS data base could then serve not only as input to models but also provide a variety of information about forest resources which can be used in "informal" models of impact evaluation (i.e., expert judgement based upon experience).

   b.) It is also critical that a contagion model framework be integrated into IPIAS. This work has begun and is tasked to the Intermountain Forest Experiment Station at Moscow, Idaho.

8) It will still be necessary to develop impact prediction models for recreation, esthetics and other socioeconomic concerns for some Forest applications of IPIAS if forest management efforts in those particular cases have needs for such impact predictions.

a.) The technology for esthetic impact evaluation exists. Work efforts should be aimed at integrating these modeling technologies into currently used scenic impact evaluation methods and also tying these models into GIS data input formats. For example, it should be possible to integrate GIS data bases with VIEWIT programs as currently used within the United States Forest Service and to have a common GIS serve as input to both VIEWIT and scenic impact models which use forest and topographic characteristics as predictors of visual impacts of management actions.

b.) There likely should be some <u>new</u> model development for recreation impacts. Currently there are no known recreation impact models which could be linked to physical resource attributes. Work should be accomplished oon the problem of predicting recreation visitation changes as a result of physical resource modification, whether that modification comes from direct pest impacts or management actions which respond to pest problems.

9) Greater attention should be paid to the interfaces between silvicultural, watershed and forest engineering models and data requirements. It apppears that important interactions exist between these three areas of forest management and manipulation. More effort should be directed at the identification of these interactions and appropriate impact prediction models and data requirements.

Based upon the above recommendations, it is clear to us that specific models cannot be selected for IPIAS prior to knowing the application area. Also, IPIAS must be tailored to the specific setting after assessing the needs of the specific user group.

The above guidelines and reccomendations were used in implementing a prototype of IPIAS on a demonstration forest. The Forest Pest Management Methods Applications Group in cooperation with Virginia Tech and The University of Arizona selected the Nezperce National Forest as a demonstration site for IPIAS. More specifically, the demonstration centered around an automated simulation of a manually produced project plan entitled, "Red River Mountain Pine Beetle FY 1985 Project Plan. This demonstration consisted of linking and running models which showed fisheries impacts, timber sale economics, the effects of fires on watersheds, elk habitat impacts and the costs of alternative management actions relative to road and logging practices. The on-site demonstration also permitted the assessment of the use of a geographic information system as a data input source for the impact models. A variety of data themes were used (e.g. timber, soils, streams, area transportation plan, visual quality objectives, mountain pine beetle data, topography, cultural features and precription watersheds). It is intended to expand upon this preliminary version of IPIAS and to implement a full working system on the Nezperce, Red River District in 1986.

Literature Cited

Anonymous 1983. Final report to USDA Forest Service, Forest Pest Management/Methods Application Group on a Pest Impact Assessment System Workshop. Milliken, CO, February 13-18, 1983.

Buhyoff, G. J., Wellman, J. D. and Daniel, T. C. 1982. Predicting scenic beauty for mountain pine beetle and western spruce budworm damaged forest vistas. Forest Science. 28:827-838.

Buhyoff, G. J. and Daniel, T. C. 1984. Integrated pest impact assessment system: development and operations coordination. USDA Forest Service, Coop. Agreement 28-C4-320, FY84 Progress Report, September 1984.

Buhyoff, G. J. and Daniel T. C., 1984. Integrated Pest Impact Assessment System: Development and Operations Coordination - FY 84 - Progress Report. Prediction Model Survey and User Needs Assessment. Submitted to U.S.F.S., FPM/MAG, Fort Collins, Colorado.

Daniel, T. C., White, W. B. and Hunter, D. O. 1983. Integrated pest impact assessment system: an interface to a forest management information system. USDA Forest Service, Forest Pest Management Methods Application Group, Fort Collins, CO Rpt. No. 84-2, 22 pp.

Leuschner, W. A. 1979. Impact analysis, interpretation, and modeling. In. Waters, W. E. (ed) Current Topics in forest entomology: selected papers from the XVth international congress of entomology. USDA Forest Service General technical Report WO-8. U.S. Government Printing Office, Washington, D. C., pp. 50-53.

Mason, G. N. 1984 (Revised June). Southern pine beetle predictions handbook. USDA Forest Service, Integrated Pest Management RD&A Program, Southern Region, Atlanta, GA.

Rykiel, E. J., Saunders, M. C., Wagner, T. L., Loh, D. K., Turnbow, R. H., Hu, L. C., Pulley, P. E. and Coulson, R. N. 1984. Computer aided decision making and information accessing in pest management systems, with emphasis on the southern pine beetle. Journal of Economic Entomology. 77:1073-1082.

Schroeder, H. W. and Daniel, T. C. 1981. Progress in predicting the perceived scenic beauty of forest landscapes. Forest Science. 27:71-80.

Thomas, J. W. (ed) 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service, Ag. Handbook No. 533. 512 pp.

FISCAL YEAR 1986 DETAIL

VISUAL IMPACT ASSESSMENT MODULE

FOR THE

INTEGRATED PEST IMPACT ASSESSMENT SYSTEM

Terry C. Daniel

and

Robert Itami

University of Arizona

Visual impact and landscape quality assessment have become an essential part of the management of public lands. The <u>Visual Resource Management</u> (VRM) system of the U.S. Bureau of Land Management (USDI BLM, 1980) and the <u>Visual Management System</u> (VMS) of the U.S. Forest Service (USDA FS, 1979) are the most established formal systems for landscape quality assessment and management currently in use. These systems are an integral part of the legislatively mandated land management planning processes of both agencies. The VRM and VMS rely on the expert judgment of a trained landscape architect or other professional, and both

follow essentially the same land classification and decision making framework outlined below:

Landscape Classification. The regional landscape is first subdivided into major physiographic sections which are considered to be homogeneous in landform and land cover. These large units may be further subdivided into sub-types based on local variations in landscape pattern. This provides a frame of reference for subsequent steps in the visual management process.

Visual Quality. The purpose of this step is "to map the variation of scenic quality across the landscape in order to identify and protect landscapes of the highest visual amenity" (Itami, in press). Both the BLM and USFS use the expert judgement of trained landscape specialists to map visual quality using physical factors such as landscape variety, topographic ruggedness, and uniqueness as criteria to judge scenic quality.

Public Sensitivity. This step provides a "measure of peoples concern for the scenic resource" (USDA Forest Service, 1974, p.18). The Forest Service VMS generates levels of sensitivity by overlaying viewsheds (visible areas), distance zones, and use areas. The BLM system uses similar criteria.

Visual Quality Objectives. Management objectives are categorized based on specific combinations of scenic quality and public sensitivity. These objectives range from maximum protection to rehabilitation of visual quality.

Visual Impact Assessment. This procedure attempts to measure the magnitude of visual impact from specific management

practices. The methods in this step contrast dramatically between the BLM method and the Forest Service approach. The BLM method measures impact by estimating contrast ratings between the visual attributes of the proposed management activity and the existing landscape. The Forest Service method uses indirect measures for estimating what is called "Visual Absorption Capability" (VAC), or the landscape's ability to absorb visual impacts.

Both the VMS and the VRM systems produce maps indicating categories of suggested management objectives/constraints based on the expert analysis of landscape visual quality and sensitivity to public views. Each attempts some assessment of the potential of each area for adverse visual impact from management activities.

In the development of the Visual Impact Assessment Module for IPIAS the basic conceptual framework described above has been largely retained. Visual assessment procedures are implemented within the framework of the larger IPIAS planning model which allows a more powerful integration of visual amenity values with other resource considerations. The VIAM approach greatly increases efficiency over the VRM and VMS procedures in that the required data base is shared with other impact and forest simulation models in IPIAS. The reliability and validity of assessments are also improved by replacing many expert judgment and hand mapping procedures with explicit computer models and GIS analysis and mapping routines.

CONCEPTUAL FRAMEWORK

Integrated Pest Impact Assessment System

The Visual Impact Assessment Module (VIAM) is one component of the larger IPIAS framework which includes models for forest growth and mortality, timber yields, stream sedimentation and fisheries, wildlife habitat, as well as insect damage models. IPIAS uses advanced GIS spatial modelling techniques to generate maps and reports giving the forest manager information from the various resource models about the impacts of alternative management plans. IPIAS utilizes the MOSS/MAPS (USDI US Fish and Wildlife Service, 1984) spatial data base and GIS operators to host a set of integrated resource production and impact models. The IPIAS database is comprised of a set of map themes (e.g., timber types, transportation, large game summer and winter ranges, recreation sites, streams and other water bodies, administrative boundaries, elevation data) which the various IPIAS models share within an integrated decision support system.

Visual Impact Assessment Module

The VIAM follows the constraints of the other models by working with existing map themes in the data base. The only base

data collected specifically for the VIAM is "Important View Points," which includes scenic overlooks, recreation areas, and scenic roads, trails and rivers which are all of potential interest to other aspects of the planning process. The VIAM is designed to parallel the existing Visual Management System (VMS) in current use by the USFS, but it is designed to utilize the capabilities of the MOSS/MAPS and other model components of IPIAS system to provide more information about visual resources. Among the enhancements is the linking of perspective graphics tools to simulate views of the study area using the digital elevation files in the IPIAS data base. Another significant difference from the existing VMS model is the design of a new model which utilizes public preferences as a basis for developing a predictive model of scenic quality.

Two subsystems, the Visual Analysis models and the observer-based Scenic Beauty models, are interrelated within the VIAM. The <u>Visual Analysis</u> component of the proposed system consists of a coordinated set of computer implemented tools to help the manager to:

1. identify important viewpoints and define their sensitivity to visible landscape modifications;

2. design alternative landscape modifications (e.g. clear-cut boundaries, thinning plots, vegetative screening);

3. determine and display the extent of potential visual impacts associated with a proposed landscape alteration;

4. simulate the visual effects of the proposed alteration for selected views using computer generated perspective displays.

The Scenic Beauty Model component of the VIAM provides estimates of the perceived scenic beauty of individual scenic vistas. Scenic beauty indices are based on public aesthetic judgments and refer to the view of the area that is proposed for modification as seen from some designated view point.

The Vista Scenic Beauty model is an extension of work by Brown and Daniel (1984) which produced a predictive model of public preferences of near-view forest scenes using physical characteristics of forest stands such as amount of downed wood, size and number of trees, and other "manageable forest features." Work by Buhyoff, Wellman and Daniel (1982) showed that perceived scenic beauty of vistas could be predicted from photo based measures of large scale landscape characteristics (e.g. percent of scene in dense forested vegetation, percent of open foreground). The Vista models being developed for the VIAM pose many challenges, but can potentially go well beyond the limits of the earlier modelling efforts. Using the GIS technology and forest simulation models in IPIAS, vista scenic beauty can be predicted directly from variables in (or computed from) the geographically referenced IPIAS data base.

VISUAL ANALYSIS

In the existing Forest Service VMS the assessment of public

sensitivity takes into consideration the importance of use areas (viewpoints), distance zones, and viewsheds. These three variables are combined to define public sensitivity levels. The VIAM utilizes a similar strategy for mapping visual sensitivity:

Selecting viewpoints. Significant viewpoints are selected along major roads, residential and tourist areas, recreation areas, and designated scenic overlooks. They are then rated according to the number of viewers, viewer contexts and the significance of the viewpoint (eg. national, state or local designations).

Visual Accessibility. Visual accessibility is mapped by plotting viewsheds for each viewpoint; a viewshed is the geographic area that can be seen from the viewpoint.

Distance Zones. Distance zones are mapped from each viewpoint using proximity measures in MOSS. Landscapes that are closer to viewpoints are weighted as more sensitive to impact than are more distant landscapes.

Composite Visual Sensitivity. View sheds for all designated Important View Points are weighted for distance zone and then combined (overlayed) to obtain a composite map of Visual Sensitivity. Areas that are seen by more viewpoints at closer distances are scaled as more sensitive.

VISUAL SIMULATION

Visual resource specialists frequently use tools such as PERSPECTIVE PLOT or PREVIEW to generate computer graphic

simulations of landform and vegetation. These tools are extremely helpful in determining potential visual impacts of various management activities. The IPIAS VIAM will generate perspective view simulations directly from the IPIAS data base with a minimum of user input.

PREVIEW (Myklestad and Wager 1976), a perspective simulation package written in Fortran V, is being rewritten in Fortran 77 and adapted to read digital elevation and timber stand files directly from the MOSS/MAPS data base in IPIAS. Forest vegetative cover (tree types, densities, heights, etc.) is read from output files created by PROGNOSIS and the associated COVER and MPB/CONTAGION components of IPIAS. This allows management plans and resulting modelled changes in forest characteristics to be used to generate visual simulations directly. This is a superior approach to existing techniques because the GIS data base is used for multiple purposes avoiding the current practice of redundant digitization of elevation and vegetation data for the sole purpose of producing perspective simulations. Further, this integration assures that the visual impact assessment is based on the same input as the other IPIAS models, thus improving the manager's ability to evaluate trade-offs with other impacts and resource goals.

SCENIC BEAUTY MODELS

Visual quality assessment in the existing VMS model derives scenic quality classes based on professional judgments about the

visual "variety" of landscape elements. In the VIAM approach scenic beauty is determined from public preference ratings of representative views of the landscape. Vista scenic beauty models are based on relationships between public perceptions of the view and landscape features falling within the seen-area of the modeled viewpoint.

Perceived scenic beauty of scenic vistas will be related to the set of spatially distributed landscape features falling within the viewshed of the vista. Relationships among relevant landscape features, relative to viewer position, will be systematically measured and quantitatively related to indices of perceived scenic beauty. The powerful GIS operators in MOSS, including perspective transformations of map data, provide an efficient means of obtaining these measures. The modelling of vista scenic beauty can provide better tools for managing scenic beauty, and a more positive way of integrating visual quality objectives into the multiple-use planning and management framework.

VISUAL IMPACT ASSESSMENT

Visual impact assessment in the VMS process uses indirect measures such as Visual Absorption Capability or in the BLM method, contrast ratings. These measures may imply the direction of impacts on visual quality, but no attempt is made to predict the magnitude of change in scenic beauty. The VIAM method

provides a powerful, integrated system for more precise and efficient visual impact assessment. Impacts on scenic beauty are modelled directly from measured or projected changes in relevant themes in the spatial data base. These changes may represent effects of proposed management activities developed in the plan formulation process, or natural occurrences such as forest fires or insect damage. Scenic beauty is modelled for specific viewpoints, giving the manager a more precise assessment and more flexible options for mitigating visual impacts.

An important part of the interactive approach to modelling visual impact is the ability to request visual simulations of impacts directly from the GIS data base. "Before" and "after" views may be requested, or representations of visual effects as seen from different viewer positions can be generated. The VIAM also provides the manager with statistical summaries of the size of the impact, and the predicted change in public perception of scenic beauty for each view.

BIBLIOGRAPHY

Brown, T.C. and T.C. Daniel (1984) Modeling Forest Scenic Beauty: Concepts and Application to Ponderosa Pine. USDA Forest Service

Research Paper RM-256, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Brown, T.J. and R.M. Itami (1982) "Landscape Principles Study: Procedures for Landscape Assessment and Management-Australia", Landscape Journal, 1:Fall pp.113-121

Buhyoff, G.J. and J.D. Wellman (1980) "The Specification of a Non-Linear Psychophysical Function for Visual Landscape Dimensions", Journal of Leisure Research, Vol. 12:3 pp. 257-272

Buhyoff, G.J., J.D. Wellman and T.C. Daniel (1982) "Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas". Forest Science 25:837-838.

Buhyoff, G.J., L.K. Arndt, and D.B. Propst (1981) "Interval scaling of Landscape Preference by Direct and Indirect Measurement Methods", Landscape Planning. vol. 8: pp. 257-267

Craik, K.H. and N.R. Feimer (1979) "Setting Technical Standards for Visual Assessment Procedures" in Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource. G.H. Elsner and R.C. Smardon technical coordinators, USDA Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-35, Berkeley,

CA.

Daniel, T.C. and R.S. Boster (1976) Measuring Landscape Esthetics: The Scenic Beauty Estimation Method. USDA Forest Service Research Paper Rm-167. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Daniel, T.C. and H. Schroeder (1979) "Scenic Beauty Estimation Model: Predicting Perceived Beauty of Forest Landscapes " in Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource. G.H. Elsner and R.C. Smardon technical coordinators, USDA Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-35, Berkeley, CA.

Daniel, T.C., W.B. White, and D.O. Hunter (1984) Integrated Pest Impact Assessment System: An Interface to a Forest Management Information System USDA Forest Service. FPM/MAG Report No. 84-2, Fort Collins, CO.

Daniel, T.C. and J. Vining (1983) "Methodological Issues in the Assessment of Landscape Quality", in: I. Altman and J.F. Wohlwill (Editors), Human Behavior and Environment Vol 6.. Plenum Press, New York, pp. 39-84

Daniel, T.C. and E.H. Zube (1979) "Assessment of Esthetic Resour-

ces", Assessing amenity resource values. USDA Forest Service General Technical Report RM-68, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Feimer, N.R., R.C. Smardon and K.H. Craik (1981) "Evaluating the Effectiveness of Observer Based Visual Resource and Impact Assessment Methods", Landscape Research. Vol. 6:1 pp. 12-16

Gimblett, H.R., R.M. Itami, J.E. Fitzgibbon (1985) "Mystery in an Information Processing Model of Landscape Preference", Landscape Journal , University of Wisconsin Press, Ann Arbor, Michigan

Itami, R.M. (In Press) "Scenic Perception: Research and Application in U.S. Visual Management Systems" in Canadian Western Geographic Series. P. Dearden, Editor, University of Victoria, Canada.

Kopka, S. and M. Ross (1984) "A Study of the Reliability of the Bureau of Land Management Visual Resource Assessment Scheme", Landscape Planning. Elsevier Science Publishers, Amsterdam, Vol 11 pp. 161-166

Laughlin, N.A. (1984) "Attitudes of Landscape Architects in the USDA Forest Service Toward the Visual Management System" unpublished MLA thesis, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Miller, P.A. (1984) "A Comparative Study of the BLM Scenic Quality Rating Procedure and Landscape Preference Dimensions", Landscape Journal, Vol. 3:2 pp.123-135

Myklestad, Eric and J.Wager (1976) "PREVIEW: Computer Assistance for Visual Management of Forested Landscapes," Research Paper NE-355, 1976, USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA.

Porteous, D. (1982) "Approaches to Environmental Aesthetics", Journal of Environmental Psychology, Academic Press Inc., London, Vol 2: pp. 53-66

Schroeder, H.W. and T.C. Brown (1983) "Alternative Functional Forms for an Inventory-Based Landscape Perception Model", Journal of Leisure Research. National Recreation and Park Association. Vol 15:2 pp. 156-163

Sheppard, Stephen R.J. (1985) "Illustrating Future Landscapes: A User's Guide to Visual Simulation" unpublished manuscript.

Smardon, R.C., N.R. Feimer, K.H. Craik, and S.R.J. Sheppard (1983) "Assessing the Reliability, Validity and Generalizability of Observer-Based Visual Impact Assessment Methods for the Western United States", in Managing Air Quality and Scenic

Resources at National Parks and Wilderness Areas R.D. Rowe and L.G. Chestnut (eds), Westview Press, Boulder, Colorado pp 84-101

Travis, M.R., G.H. Elsner, W.D. Iverson, and C. Johnson (1975) "VIEWIT: Computation of seen areas, slope, and aspect for land-use planning." Technical Report PSW-11/1975, USDA Forest Service, Berkeley, CA.

Twito, Roger and J.Warner (no date) "Perspective Plot Program for Evaluating Visual Impact of Proposed Timber Harvest Units with Desktop Calculator, Plotter and Digitizer" USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

USDI Bureau of Land Management (1980a) Visual Resource Management Program BLM Division of Recreation and Cultural Resources, Washington D.C.

USDI Bureau of Land Management (1980b) Visual Simulation Techniques BLM Division of Recreation and Cultural Resources, Washington D.C.

USDI Bureau of Land Management (1984) "8400 - Visual Resource Management" (revision, release 8-24), Washington, D.C.

USDA Forest Service (1974) National Forest Landscape Management,

Volume 2, chapter 1 The Visual Management System, Agriculture Handbook Number 462, Washington, D.C.

Zube, E.H., J.L. Sell and J. G. Taylor (1982) "Landscape Perception: Research, Application, and Theory", Landscape Planning. Vol 9:1 pp. 1-33

FISCAL YEAR 1987 DETAIL

FOREST IMAGE DATA BASE SYSTEM

The goal of this part of the 1986/87 work was to develop a prototype to demonstrate possible applications of interactive laser disc technology as an adjunct to the decision support functions of IPIAS. The system was to provide 1) a computer addressable data base of ground level color images of inventoried forest sites (stands) and 2) a system for finding forest sites in the data base that match (within specified error parameters) simulated forest stands that represent model (e.g., PROGNOSIS) projected outcomes of alternative management actions. Color images of forest stands can provide managers and resource professionals with useful information about stands that may not be readily communicated by the more abstract quantitative representations in typical tabular data bases or growth model simulations. This additional information may be particularly important for wildlife or recreation specialists, landscape architects and for concerned members of the public interested in the state of the forest. Further, the image data base on laser disc can serve as a virtually permanent, high fidelity archive, providing a visual history of forest conditions and changes.

The initial pilot system was developed in cooperation with the Management Information Systems Department at the University of Arizona. It is implemented on an NCR INTERAC-TV II interactive laser disc system consisting of an NCR PC-6 micro computer with color monitor linked to a standard laser disc player by an interface board. System software, the users guide and systems maintenance manuals, and copies of the laser disc containing the color imagery are being delivered with this report.

Advantages of laser disc for this application include

high storage capacity--the equivalent of over 50,000 full color photographs (or color slides) can be stored on one disc;

high fidelity--images are stored in an analog format so the resolution of the displayed image is only constrained by the quality of the monitor on which it is displayed;

permanence--video disc images will retain their original fidelity after thousands of uses and the disc itself is virtually indestructible;

rapid access--any of 50,000+ images on the disc can be accessed by computer software and displayed on the monitor in fractions of a second; and

economy--the cost of "pressing" a laser disc has continually gone down over the last few years so that the cost for the original disc is now under $2500, with as many virtually perfect copies as desired available

for about $20 each. The major costs of developing the disc, then, are the collection of the original imagery (color slides) and the transfer of these images to an appropriately produced "master" video tape (master tape costs for the pilot disc were about $.65 per color slide, but could be below $.50 per slide with minor additions of automated equipment).

The image data base can be used as a direct parallel to typical forest inventory data bases, by providing ground level photographs (stored as video images or "tracks" on laser disc). Users of the system can call up data summaries for selected forest stands, such as size-density class tables, ground cover and downed wood, and in addition see color video images of the same stands displayed on the color monitor. Video images are retrieved by data base management software and the laser disc interface hardware and displayed to the TV monitor in fractions of a second. The user is then allowed to sequentially view any of the images available for the selected stand (the pilot system has only four randomly selected images per stand) and to "toggle" between the images and several tabular summaries of typical forest inventory data for the stand.

The second use mode for the system is designed to augment the projections of forest stand conditions provided by forest growth simulation models, such as the PROGNOSIS model used in IPIAS. Typical output from these models is in the form of extensive tables of quantitative parameters (e.g., stems per acre per species per size class). For some applications these tables are quite sufficient, especially when explicit models have been developed to translate projected parameters into estimated biological or socio-economic effects. For other applications, such as many wildlife habitat concerns, recreation and visual impacts, and for communicating projected outcomes to the public, abstract quantitative tables are less sufficient. In this context, the image data base system is designed to search the stored quantitative data base (for previously inventoried stands) to find stands that match (within specified error margins) the quantitative characteristics of the simulated stand. Appropriate stands are typically found within a few seconds, and the user may then view video images of stands that are similar to the simulated stand. Further, the system allows the user to toggle repeatedly between the images of a selected stand and inventory data summaries for that stand.

In either the inventory or the simulation model applications of the image data base system, users should find the addition of "real" ground based pictures helpful in developing a more concrete understanding of the forest and the changes projected for managed stands. The success of such a system will depend upon having well documented biological data and carefully coordinated color pictures for large numbers of forest stands. The first requirement is already partially met within the routine timber stand inventory procedures of the Forest Service, and this data will increasingly be augmented with other biological and physical inventory information under current "integrated resource management" trends. Adding ground-based color

photography (or video imagery) would be a low additional cost to inventory procedures. With an interactive laser disc system, that imagery would be available in a rapid computer accessible system that is directly linked to the biological data base.

IPIAS VIDEO PRODUCTION

The goal of the IPIAS video production was to effectively communicate the capabilities of IPIAS to potential users within the natural resource management community--especially the US Forest Service. The need for such a production was identified in the context of technology transfer planning, as described above. The purpose of the video program was to arouse interest among potential users of IPIAS in order to begin to expand the potential clientele for the system. Thus, the video does not attempt to present all of the technical details of the system, nor does it present every function that the system performs. Rather, the program highlights the type of management problems that IPIAS can support and some of the advantages of using an integrated computer decision support system.

Previous efforts provided convincing evidence that quality video productions require experienced professional assistance. Thus, the production staff of KUAT-TV, the PBS affiliate station at the University of Arizona, was contracted to produce the IPIAS video. After several design meetings with their staff to establish goals and a basic "story board," a team consisting of an executive producer, a script writer and a videographer was identified. The video production staff joined members of the IPIAS development team (White, Hunter, and Daniel) for two weeks on the Red River Ranger District in Idaho and at the Basin-Thompson Project site near Butte, Montana.

Over five hours of professional three-quarter inch video was collected to provide the basis for the final production. Major management problems and goals on each district were documented, with both agency and public perspectives represented. In addition, IPIAS capabilities and example outputs were video taped for inclusion in the program. Music and graphic titles were also commissioned. The final production, which is being delivered along with this report, is a 15 minute broadcast quality program available on either three-quarter inch or standard VHS video cassette. Distribution of the program will be directed by FPM/MAG.

In addition to the final video program, there are also many hours of professional quality video tape that provides unedited documentation of the Red River and Basin-Thompson applications of IPIAS, as well as reviews of more general forest management problems and activities. This archival resource should prove very valuable for future video productions, whether of broadcast quality or for more utilitarian, "in-house" uses. Indeed, both the Nezperce and the Deer Lodge National Forests have already requested specific segments for training and public involvement uses.

TECHNOLOGY TRANSFER PLAN--DRAFT

IPIAS TECHNOLOGY TRANSFER PLAN

DRAFT

Terry C. Daniel
University of Arizona
and
Gregory J. Buhyoff
Virginia Tech

BACKGROUND

The Integrated Pest Impact Assessment System (IPIAS) is a computer implemented decision support system designed to assist forest managers with the implementation of Forest Plans. IPIAS assists in the location and selection of project areas and in the formulation and evaluation of alternative management strategies and actions that may be applied to that area. Key elements in the system include a geographic data base and geographic analysis and modeling operators (i.e., a Geographic Information System, GIS), a forest inventory data base linked with a forest growth and mortality simulator, and an integrated set of resource impact models that project the environmental, economic and social consequences of alternative forest management actions. All of these components are coordinated through a central shell or executive program that interacts with the user to specify analyses and management alternatives, to execute the various GIS operations and impact models called for by the analyses, and to report projected resource impacts for each management alternative under consideration.

IPIAS has been under development for four years, preceded by a three-year program that identified and tested some of the basic design concepts and features of the system. IPIAS features a modular design which facilitates implementation for new management problems and areas. The specific tabular and geographic data bases and the resource impact models in the system can be changed readily, without affecting the operation of other components of the system. The IPIAS shell does, however, assist the user in entering or editing data and in selecting response models required to answer the "what-would-happen-if" questions that are of interest. The Report Generation component of IPIAS displays resource outputs and impacts in screen or hard copy tables, graphs or maps as desired by the user.

Integrity of data and of the individual response models is left to the user--IPIAS does not provide response models, for example, but integrates and implements models provided by the user. Thus, each implementation of IPIAS requires users to select and install the models that they wish to include. Models are modified only as necessary to integrate them with other models and systems within IPIAS.

A pilot version of IPIAS has been implemented on the Red River Ranger

District, Nezperce National Forest, Idaho. The configuration of this pilot system reflects the principal concerns identified by the Forest. The target problem is to determine appropriate management responses to an outbreak of mountain pine beetle in lodgepole pine forests. A major concern is the impact of stream sedimentation, caused by road building and logging activities, on anadromous fisheries, especially migrating salmon. In response to this problem the Red River implementation of IPIAS emphasized models to predict mountain pine beetle (MPB) induced mortality and spread by developing MPB damage and "contagion" models to be integrated with the PROGNOSIS forest growth and mortality simulation program. Other models integrated for this initial application included an elk habitat model (Northern Idaho Elk Guidelines) and an economic costs and benefits model (DLOG- PRICE). Additional model developments initiated within the Red River IPIAS program includes a Visual Impact Assessment Module.

A second implementation of IPIAS has begun on the Deer Lodge National Forest near Butte, Montana. This second implementation is, in part, a field test of the processes required to transfer IPIAS technology to new forest management situations. As in Red River, an outbreak of mountain pine beetle in lodge pole pine forests provides the major impetus for management action. For this application, however, the principal resource impacts that are of concern are different. The project area is very close and prominently visible from the city of Butte. It also contains an inter-state highway, a nationally designated recreation area, a municipal watershed and reservoir, and a significant commuter home development. Thus, visual, recreational and residential property values are all of great concern, requiring the addition of appropriate new data themes and models. Forest growth and mortality, mountain pine beetle, elk habitat and sedimentation model components that were implemented for the Red River application may also require calibration and revision for application to the Montana project area.

The transfer and implementation of the Red River version of IPIAS to the Deer Lodge National Forest project area provides an important opportunity to identify problems that may be associated with more general dissemination of IPIAS technology within the Forest Service. The purpose of the 1987/88 work to be cooperatively conducted by the University of Arizona and Virginia Tech, and reported below, was to develop a "technology transfer plan" designed to make IPIAS capabilities available throughout the US Forest Service. The draft plan presented below is based on a review of technology transfer methods, on formal and informal interactions with IPIAS users and with other forest management staffs, and on the goals and philosophy that have been developed over the past four years by the IPIAS development team and the national Steering Committee.

IPIAS TECHNOLOGY TRANSFER PLAN

Transfer of the IPIAS decision support system must be a dynamic, evolutionary process. The system itself will undoubtedly continue to

be extended and enhanced to take advantage of experience gained in new applications. User needs will also change as they gain experience with the system. Other change agents will be modifications in computer hardware configurations and capabilities, new developments in data and resource response models and associated software, as well as changes in the policies and practices that define the task of forest management. Thus, the technology transfer plan must specify a continual process, rather than a static set of manuals and methods. In effect, there will not be any point in time when the transfer of IPIAS can be said to be complete; indeed there will not be any point in the process where IPIAS itself can be said to be complete. It is more likely that the development of IPIAS will be an ongoing process, and adoption and applications of the system will initiate a process of developing a "new way of doing business," so that eventually it will be difficult to identify which results of the process are, and which are not, directly attributable to IPIAS.

Consistent with the above philosophy, the technology transfer plan for IPIAS is conceived as a process, cycling through six stages of interaction between the system (or its developers) and the user-clients. The first stage, Identify User Needs, has been a constant emphasis in the development of the system to date. The design and development of IPIAS involved intensive interaction with users at many levels, from the individual managers who might operate the system to forest, regional and national level management and policy specialists on the IPIAS Steering Committee. The second stage, Evaluation, is a critical component of the transfer plan designed to insure that the current version of IPIAS is tested and ready for transfer to new applications. The third phase, Publicity and Marketing, focusses upon making the capabilities of the system known to potential user-client groups; i.e., the process of locating and establishing communication with appropriate resource management agencies and staffs. After an interested user and a set of needs have been identified, the fourth stage, Tailoring the Application, is initiated. In every IPIAS application, the specific set of geographic and tabular data, the resource impact models, and other components of the system will have to be individually configured. This "tailoring" will require intensive interaction with the user. Once the configuration is determined, Transfer and Installation of the IPIAS software on the user's computer system must be accomplished. The final stage, Training and Support, requires frequent or continual interaction between the user and the system developers and/or maintainers and will tend to recycle the process through the preceding stages.

Each of the stages of the technology transfer plan are described in more detail below. Some of these processes have already been initiated, and others are planned for implementation in the next year. Transfer processes that are associated with a specific implementation of IPIAS are initiated individually as a client-user is identified. The Training and Support processes are continuous. The Evaluation phase of the transfer plan is repeated on ever "cycle" to insure that an appropriately tried and tested version of the basic IPIAS shell is available for adoption and implementation. At the same time, it is realized that each implementation will present unique requirements

that must be met by the addition of specific tailor made components and by application-specific modifications of the system.

IDENTIFY USER NEEDS

Much of the development of IPIAS to date has been directed by interactions with potential and actual users of the system. The preliminary model for the current version of IPIAS was developed through intensive interaction with staffs of the Pike-San Isabel National Forest and Region 2 Forest Pest Management. The design of the second generation of IPIAS was developed in a week-long workshop held at Milican, Colorado (FPM/MAG, February, 1983). A national panel of forest management, planning, policy and research specialists reviewed and evaluated the initial pilot system and concept and then worked together to prepare a plan for further development of the system. The Milican Plan has been reviewed and modified at annual meetings of the national IPIAS Steering Committee, which is composed of representative management, planning, research and systems specialists.

Following the Milican plan, a formal assessment of user needs was conducted (Buhyoff, et al, 1986, FPM/MAG Report 86-5). A combination of mail and telephone surveys and personal interviews contacted forest management and planning personnel in District, Forest, Regional and Washington Office staffs. The survey effort was intensified in Regions 1 and 6, where every forest management and planning unit was surveyed to determine what resource response and management models were being used, how frequently, implemented on what equipment, and with what degree of user satisfaction.

Analysis of the user needs assessment revealed intensive use and reliance on computer implemented mathematical models in forest silviculture, engineering (roads), pest management, and in economic projections associated with timber production and management costs. Resource specialists in areas such as wildlife, recreation and visual esthetics were using less quantitative models, typically "guidelines" or standardized systems for organizing and documenting expert judgments, and these were rarely implemented on computers. Thus, the survey revealed a wide gap in the availability and use of systematic models among the various resource management units involved in multiple resource management of the forest.

Another theme revealed by the survey was a lack of coordination and integration of models. A number of management and planning units reported using stand alone models that were frequently developed by and for a particular forest or even an individual district. Documentation of these models was sometimes very sparse or non-existent. Relatively little evidence of testing or standardization of models was reported, and there were very few instances of separate models being integrated into more comprehensive management support systems. At the same time, there was considerable expression of the need for more reliable models and for better integration.

A noticeable exception to the trend cited above was the PROGNOSIS family of models and extensions. This was by far the most frequently used computer implemented model in Regions 1 and 6, with some silvicultural units reporting more than a thousand runs per year. Most users were reasonably satisfied with the basic forest growth and mortality components of the PROGNOSIS model and, while reported use was relatively light, with some of the extensions. Some users noted the need for improvements in the model for better application to specific forest types and management regimes. A number of users found the need to access and run the model on the Fort Collins main frame computer facilities to be inconvenient, and occasionally impossible when the system was under heavy user loads.

Aside from the "extensions" specifically built into PROGNOSIS, there were very few reports of attempted or developing efforts to integrate the system with other models. Important examples included efforts to link PROGNOSIS COVER output to an elk habitat model and efforts to use PROGNOSIS in conjunction with mountain pine beetle and spruce budworm hazard rating systems. A frequently cited need was for better linkage between PROGNOSIS, and other models, and the geographic data base for the forest. Several units reported exploratory use of computer implemented GISs, but there were no reports of GISs being directly linked to resource models or to inventory-type data bases. A number of survey respondents and individually contacted management and planning specialists cited the need for aggressive development in this direction.

Based on the user needs assessment survey, Buhyoff, et al characterize forest planning and management, with particular reference to Regions 1 and 6:

> The use of computer-implemented models of forest growth and mortality is intensive, widespread, and increasing for timber management and related pest management concerns. The influence of model projections on the formulation and selection of forest management alternatives is currently substantial, and promises to increase, especially given the growing availability of the computer hardware that is required for efficient use of these models. This scenario provides substantial impetus for the parallel development of systematic, computer implemented models to represent other forest management concerns. In this regard, Forest Pest Management has set an important example by using models of insect infestation and damage that are intimately interrelated with the dominant forest growth and yield models. (p. 10)

Based on this assessment, the IPIAS program development has emphasized the integration of multiple resource response models and close linkages with both geographic and tabular data bases. User preferences ascertained in the survey also supported the need for implementing the system as much as possible on the local forest or even district level computer hardware, minimizing the need for remote access to main frame facilities. Another major contribution of the IPIAS research and development program has been to encourage and

facilitate the development and integration of appropriate response models for resources such as wildlife, recreation and visual esthetics. Extended and more sophisticated pest damage and impact models, including the CONTAGION model for predicting the temporal and geographic spread of mountain pine beetle infestations, has also been a major goal of the program.

EVALUATION

A critical component in any technology development and transfer program is the rigorous evaluation of the performance of the system that is to be transferred. The IPIAS system is still under development, and will continually be evolving and changing to take advantage of related new technical developments and to respond to new user demands. However, it is important to periodically consolidate central features of the system and subject them to a substantial performance evaluation. To some extent such an evaluation has already been implemented for the Red River version of IPIAS. Ranger district staff have been using the system to support typical planning and management tasks for the past year. In that context, users have had an opportunity to evaluate the system and have been asked to regularly report on its performance under field application conditions. A number of individual problems have been identified, primarily associated with performance of specific resource response model components, but the system overall has been found a very useful and effective aid to project level planning and management.

Field tests, such as the Red River District trials, are an important part of an evaluation program, but more rigorous and directed professional system evaluations are also needed. As additional model and data manipulation components are developed and added to IPIAS, there is a rising need for an overall evaluation of the operations of the system. Of particular concern is the efficiency of the interaction among system components, the configuration of the system on operations hardware of the users/clients, and the consistency and ease of the user interface throughout the different functional components of the system. Another critical concern is that the system be sufficiently well documented and that appropriate and effective user guides and system maintenance documents and user support systems be developed and tested. It is recommended that these tasks be conducted by a "third party" professionally qualified in the development and evaluation of management information systems.

Field evaluations are expected to be a continual process, with every new application essentially becoming a new field test of the system. The more intensive formal evaluations, on the other hand, should be less frequent and reserved for points where clear "plateaus" have been reached in the development of the system. The completion of the Red River implementation of IPIAS and the beginning of the Basin-Thompson Project application would seem to provide just such a plateau. Therefore, it is recommended that a formal and rigorous third-party evaluation of the IPIAS decision support system be a high priority for the immediate future of the development program.

PUBLICITY AND MARKETING

Critical to the success of any technology transfer program is an informed and receptive group of potential users. There can be no demand for a system that no one knows about, and without user demand there is little point in developing a plan for transferring the system to them. Traditional methods for "advertising" the availability of a new management support system include publications in trade and professional journals, presentations at symposia and professional association meetings, and mailed out brochures, pamphlets and other written materials. All of these vehicles have and will be used in publicizing the capabilities and availability of IPIAS.

Perhaps the most effective publicity for the IPIAS program has been the personal contacts established by members of the Steering Committee and the development team. The current application of the system on the Nezperce National Forest, and the applications that are being initiated on the Deer Lodge and Nicolet National Forests all arose from personal contacts and discussions with members of the IPIAS development team. It is expected that personal contacts will continue to play a key role in the dissemination of IPIAS technology, and will be essential in the actual implementation of the system on specific forests.

A number of government reports and professional journal publications have already been generated to document and publicize the IPIAS development effort. IPIAS team members have also presented demonstrations and talks about the system in a wide array of meetings and workshops at national and regional levels. This effort will continue as a natural part of the research and development program. In the summer of 1988, an International Symposium on the Application of Advanced Technology to Natural Resource Management, Resource Technology 88, will be held in Fort Collins, Colorado. Members of the IPIAS development team initiated this symposium to provide a forum for presenting and discussing the rapidly expanding application of computer and other advanced technologies in the natural resources field. IPIAS will be featured as part of this international trend. The symposium and the associated publication of invited papers will help to provide exposure of IPIAS, in the context of other technological advances in natural resource management, to an international audience of interested managers and scientific researchers.

It is generally agreed that in the age of color television, written media have lost much of their appeal and effectiveness for disseminating information. In recognition of this fact, a broadcast quality video tape program to expose the capabilities of IPIAS was identified as an important part of the technology transfer program. Such a program is being produced focussing upon the Red River District, Nezperce National Forest, implementation of IPIAS and on the subsequent application to the Basin-Thompson Area on the Deer Lodge

National Forest near Butte, Montana. The video program is being produced by KUAT-TV, a PBS affiliate station at the University of Arizona. The production crew (producer, videographer and writer) was in the field for two weeks in the summer of 1987 and collected over five hours of video taped interviews and forest resource and management action sequences. This "raw material" has been edited into a 15-minute broadcast quality video program that is available on three-quarter inch and standard VHS video cassettes. Copies of the final program have been delivered along with this report for distribution by FPM/MAG.

The plan is to distribute the video tape program to appropriate forest and other natural resource management units nation wide. The emphasis of the program is on the growing complexity of multiple resource management, the additional difficulties introduced by such factors as increasing human demands on resources and natural hazards such as the mountain pine beetle outbreak, and the resulting need for more advanced, more powerful management tools. The program does not present the details of the IPIAS decision support system, but it does highlight the need for such a system and effectively displays a sample of the system's current capabilities. The goal is to make potential users aware of IPIAS and to arouse their interest in the system. Coupled with appropriate follow-up and the other components of the technology transfer plan, the video program is expected to play a vital role in having the system adopted by resource managers.

TAILORING INDIVIDUAL APPLICATIONS

The primary goal of the <u>Publicity and Marketing</u> component of the technology transfer plan is to arouse interest and establish contact with potential adopters of the system. Once an interested potential user is identified and contacted, the applicability of IPIAS to that users management needs must be evaluated.

Critical requirements that must be met include availability of adequate personnel resources and access to necessary computer facilities. In addition, IPIAS requires that both tabular (e.g., stand inventories) and geographic data (e.g., management unit boundaries, topography, etc) be available and of good quality. This frequently requires significant amounts of data verification and editing and, for the GIS element of the system, digitizing of multiple "themes" (maps) of relevant forest resources. Appropriate forest simulation (growth and mortality) and resource response models must also be available, or the user must be willing and able to develop such models. Another major concern is that adequate time be made available for personnel to work with the IPIAS team to implement the system for their specific application, including time for training and practice in the use of the system.

If the requirements can be met, the process of designing an IPIAS implementation for the user's particular application can begin. This is a custom "tailoring" process that requires direct interaction between the user and the IPIAS team. Application specific data,

models and other components must be modified and fit into the IPIAS framework. This will frequently require modifications and/or additions of IPIAS software. In some instances, this process can be rather straight forward, as when the basic forest growth and mortality models are the same as have been implemented in previous IPIAS applications. The tailoring process can be much more difficult, however, if many previously developed components of the system have to be substantially modified or replaced, or if entirely new components are required. Every effort has been made to insure that IPIAS is flexible and relatively easy to adapt to specific applications. However, the more changes and additions that are needed, the more effort and interaction will be required between the user and the IPIAS team to tailor the system for the application.

At the present stage of IPIAS development, the tailoring process will require rather intensive interaction between new users and personnel who are intimately familiar with the system. At present, only those individuals who have been directly involved with the system's development would be technically capable of serving in this role. It is obviously very desirable, indeed it is essential, that a transfer system be developed that is more independent of the availability of specific personnel. One proven approach to rectifying this situation is to train additional personnel to fill this role. Early users of the system being among the most likely candidates for such training.

Training new personnel would solve part of the custom tailoring problem, and could also serve another essential function, a standing system transfer, maintenance and support capability will be needed as additional users adopt the system. However, in the longer term, if IPIAS (or some related future generation system) were to be adopted by a large number of management units in different parts of the country, the demands for technical support and guidance could quickly exceed the capability of any reasonable sized technology transfer unit. For that reason, it is recommended that future research and development efforts be directed at "automating" the transfer process to the extent possible. A potentially fruitful approach would be to develop an <u>expert system</u> that would interactively assist users in designing and tailoring IPIAS to meet their needs. Such systems can be very sophisticated and could even assist users in making software modifications and in developing or modifying response models and data bases. The same system could also be used in the actual porting and installation of the system, as described in the following section.

TRANSFER AND INSTALLATION

Once it has been determined that IPIAS is to be implemented, and the design and integration of the necessary components has been developed, the next step is to actually transport and install the custom tailored software at the application site. This process can be rather straight forward, if the computer hardware environment is adequate and compatible with the software, and if computer use policies provide for sufficient access. In any case, close interaction with the system controller will be necessary to find a configuration that is efficient

and compatible with the other operations supported on the system.

In addition to the issues regarding the configuration of IPIAS on the central computing facilities, the availability of appropriate peripheral devices, especially graphics capable terminals and hard copy output devices must be assured. This can prove troublesome given typically tight equipment budgets and policy restrictions on new equipment acquisitions. In this context, it is already clear that a greater reliance on on-site microcomputer equipment would be advantageous for IPIAS. A configuration based on one of the new more powerful microcomputers as a peripheral work-station, with many IPIAS functions actually performed in that environment, would make the system more efficient and less reliant on already taxed mainframe or minicomputer facilities. Another benefit of this approach is that it would increase the ease of linking IPIAS to a variety of hard-copy and other peripheral devices, and facilitate linkage with powerful "desk-top publishing" systems. A specific review of potential configurations, and their respective advantages and disadvantages for IPIAS development and use should be undertaken in the very near future.

TRAINING AND SUPPORT

To date the training and support of new users of IPIAS has been handled directly by the development team. This arrangement has sometimes been effective in bringing problems to the immediate attention of the developers. More often, responses to relatively minor problems, frequently associated with operator or systems factors unrelated to IPIAS, has taken up valuable time from central research and development tasks. Obviously, as more users are added to IPIAS this approach cannot be continued. A more efficient, and more appropriate training and support system must be developed and implemented. Ideally, this system should be in place prior to more extensive dissemination of IPIAS.

Two approaches to a more effective training and support system have tentatively been identified. The first emphasizes the development of a user network, modeled after the MOSS Users network. Key features include the training and support of new users by existing users, and the systematic sharing of information among all users of the system. The second approach emphasizes the development of software systems to provide "automatic" transfer and support of the system, and remote "auditing" capabilities to allow the central development and maintaining staff to monitor extent of use of system components and documentation of any problems or apparent system failures. Some of these functions can be provided by a more intelligent user interface and "help" system. The use and problem documentation functions can range from storage of actual key stroke sequences, to tallies of the frequency of access to individual system components. On-line user comment systems provide another useful way to monitor and document user satisfaction and problems with the system.

VISUAL IMPACT ASSESSMENT MODULE

VISUAL IMPACT ASSESMENT MODULE FOR THE INTEGRATED PEST IMPACT ASSESSMENT SYSTEM

Progress Report
Submitted by

Terry C. Daniel
and
Robert Itami
University of Arizona

VISUAL IMPACT ASSESSMENT MODULE FOR THE INTEGRATED PEST IMPACT ASSESSMENT SYSTEM

Visual impact and landscape quality assessment have become an essential part of the management of public lands. The Visual Resource Management (VRM) system of the U.S. Bureau of Land Management (USDI BLM, 1980) and the Visual Management System (VMS) of the U.S. Forest Service (USDA FS, 1979) are formally adopted systems for landscape quality assessment and management. These systems are an integral part of the legislatively mandated land management planning processes of both agencies. The VRM and VMS rely on the expert judgment of a trained landscape architect or other professional, and both follow essentially the same land classification and decision making framework outlined below:

Landscape Classification. The regional landscape is first subdivided into major physiographic sections which are considered to be homogeneous in landform and land cover. These large units may be further subdivided into sub-types based on local variations in landscape pattern. This provides a frame of reference for subsequent steps in the visual management process.

Visual Quality. The purpose of this step is "to map the variation of scenic quality across the landscape in order to identify and protect landscapes of the highest visual amenity" (Itami, in press). Both the BLM and USFS use the expert judgement of trained landscape specialists to map visual quality using physical factors such as landscape variety, topographic ruggedness, and uniqueness as criteria to judge scenic quality.

Public Sensitivity. This step provides a "measure of peoples concern for the scenic resource" (USDA Forest Service, 1974, p.18). The Forest Service VMS generates levels of sensitivity by overlaying viewsheds (visible areas), distance zones, and use areas. The BLM system uses similar criteria.

Visual Quality Objectives. Management objectives are categorized based on specific combinations of scenic quality and public sensitivity. These objectives range from maximum protection to rehabilitation of visual quality.

Visual Impact Assessment. This procedure attempts to measure the magnitude of visual impact from specific management practices. The methods in this step contrast dramatically between the BLM method and the Forest Service approach. The BLM method measures impact by estimating contrast ratings between the visual attributes of the proposed management activity and the existing landscape. The Forest Service method uses indirect measures for estimating what is called "Visual Absorption Capability" (VAC), or the landscape's ability to absorb visual impacts.

Both the VMS and the VRM systems produce maps indicating categories of suggested management objectives/constraints based on the expert analysis of landscape visual quality and sensitivity to public views. Each attempts some assessment of the potential of each area for adverse visual impact from management activities.

The Integrated Pest Impact Assessment System Visual Impact Assessment Module (VIAM)

The Visual Impact Assessment Module as it is developed for IPIAS largely follows the basic conceptual framework described above. However several key features are implemented within the framework of the larger IPIAS planning model which allows a more powerful integration of visual amenity values with other resource considerations. The VIAM approach greatly increases efficiency over the VRM and VMS procedures in that the required data base is shared with other impact and forest simulation models in IPIAS. The reliability and validity of assessments are also improved by replacing many expert judgment and hand mapping procedures with explicit computer models and GIS analysis and mapping routines.

The Visual Impact Assessment Module (VIAM) is one component of the larger IPIAS framework which includes models for forest growth and mortality, timber yields, stream sedimentation and fisheries, wildlife habitat, as well as insect damage models. IPIAS uses advanced GIS spatial modelling techniques to generate maps and reports giving the forest manager information from the various resource models about the impacts of alternative management plans. IPIAS utilizes the MOSS/MAPS (USDI US Fish and Wildlife Service, 1984) spatial data base and GIS operators to host a set of integrated resource production and impact models. The IPIAS database is comprised of a set of map themes (e.g., timber types, transportation, large game summer and winter ranges, recreation sites, streams and other water bodies, administrative boundaries, elevation data) which the various IPIAS models share within an integrated decision support system.

The VIAM follows the constraints of the other models by working with existing map themes in the data base. The only base data collected specifically for the VIAM is "Important View Points," which includes scenic overlooks, recreation areas, and scenic roads, trails and rivers which are all of potential interest to other aspects of the planning process. The VIAM is designed to parallel the existing Visual Management System (VMS) in current use by the USFS, but it is designed to utilize the capabilities of the MOSS/MAPS and other model components of IPIAS system to provide more information about visual resources. Among the enhancements is the linking of perspective graphics tools to simulate views of the study area using the digital elevation files in the IPIAS data base. The design of a new model which utilizes public preferences as a basis for develop-

ing a predictive model of scenic quality is still under development and has not been implemented in this phase of the research.

IPIAS VIAM SYSTEM

Two subsystems, the Visual Analysis models and the observer-based Scenic Beauty models, are interrelated within the VIAM. The Visual Analysis component of the proposed system consists of a coordinated set of computer implemented tools to help the manager to:

1. identify important viewpoints and define their sensitivity to visible landscape modifications;

2. design alternative landscape modifications (e.g. clear-cut boundaries, thinning plots, vegetative screening);

3. determine and display the extent of potential visual impacts associated with a proposed landscape alteration;

4. simulate the visual effects of the proposed alteration for selected views using computer generated perspective displays.

The Scenic Beauty Model component of the VIAM provides estimates of the perceived scenic beauty of individual scenic vistas. Scenic beauty indices are based on public aesthetic judgments and refer to the view of the area that is proposed for modification as seen from some designated view point.

VISUAL ANALYSIS

In the existing Forest Service VMS the assessment of public sensitivity takes into consideration the importance of use areas (viewpoints), distance zones, and viewsheds. These three variables are combined to define public sensitivity levels. The VIAM utilizes a similar strategy for mapping visual sensitivity:

Selecting viewpoints. Significant viewpoints are selected along major roads, residential and tourist areas, recreation areas, and designated scenic overlooks. They are then rated according to the number of viewers, viewer contexts and the significance of the viewpoint (eg. national, state or local designations). These are entered into the IPIAS map data base by digitizing or by using the "generate" command.

Rasterizing the pertinant map themes. All maps required for the VIAM must be rasterized from the vector maps. The maps required in the VIAM procedure include DEM (digital elevation already in raster form), timber stand maps, and the viewpoint map described above. All maps for the study area must be merged either in vector format or after they are rasterized using the MAPS "merge" command.

Visual Accessibility. Visual accessibility is mapped by plotting viewsheds for each viewpoint; a viewshed is the geographic area that can be seen from the viewpoint. This procedure is accomplished throught the MAPS "view" command. The viewshed for each important viewpoint is generated in separate map layers. Upon completion of this process each viewshed map is renumbered in a binary sequence (1,2,4,8,16 ...). The resulting maps are then summed to generate a continuous map where each sum can be decoded to its original binary sequence. This can be achieved because any combination of sums in the binary sequence will result in a unique number not repeated by any other combination.

Distance Zones. Distance zones are mapped from each viewpoint using the "buffer" command in MAPS. Landscapes that are closer to viewpoints are weighted as more sensitive to impact than are more distant landscapes. Distance zones reflect those recommended in the current visual management system: foreground (0 to 1/4 mile), middleground (1/4 to 2 miles), and background (greater than 2 miles).

Composite Visual Sensitivity. View sheds for all designated Important View Points are weighted for distance zone and then combined (overlayed) to obtain a composite map of Visual Sensitivity. Areas that are seen by more viewpoints at closer distances are scaled as more sensitive. This procedure is accomplished renumbering the binary sequence map to produce a map that shows how many viewpoints have visibility to each cell in the map. This map is then multiplied by the distance zones map so that foreground views are multiplied by 4, middleground views are multiplied by 2 and background views are multiplied by 1. This map is then summarized into three sensitivity zones by slicing the resulting map into three categories.

VISUAL SIMULATION

Visual resource specialists frequently use tools such as PERSPECTIVE PLOT or PREVIEW to generate computer graphic simulations of landform and vegetation. These tools are extremely helpful in determining potential visual impacts of various management activities. The IPIAS VIAM will generate perspective view simulations directly from the IPIAS data base with a minimum of user input.

PREVIEW (Myklestad and Wager 1976), a perspective simulation package written in Fortran V, has been rewritten in Fortran 77 and adapted to read digital elevation and timber stand files directly from the MOSS/MAPS data base in IPIAS. Forest vegetative cover (tree types, densities, heights, etc.) is read from output files created by PROGNOSIS and the associated COVER and MPB/CONTAGION components of IPIAS. This allows management plans and resulting modelled changes in forest characteristics to be used to generate visual simulations directly. This is a superior approach to existing techniques because the GIS data base is used for multiple purposes avoiding the current practice of redundant digitization of elevation and vegetation data for the sole purpose of producing perspective simulations. Further, this integration assures that the visual impact assessment is based on the same input as the other IPIAS models, thus improving the manager's ability to evaluate trade-offs with other impacts and resource goals.

SCENIC BEAUTY MODELS

Visual quality assessment in the existing VMS model derives scenic quality classes based on professional judgments about the visual "variety" of landscape elements. In the VIAM approach scenic beauty is determined from public preference ratings of representative views of the landscape. Vista scenic beauty models are based on relationships between public perceptions of the view and landscape features falling within the seen-area of the modeled viewpoint.

Perceived scenic beauty of scenic vistas will be related to the set of spatially distributed landscape features falling within the viewshed of the vista. Relationships among relevant landscape features, relative to viewer position, will be systematically measured and quantitatively related to indices of perceived scenic beauty. The powerful GIS operators in MOSS, including perspective transformations of map data, provide an efficient means of obtaining these measures. The modelling of vista scenic beauty has not been completed, but it does promise to provide better tools for managing scenic beauty, and a more positive way of integrating visual quality objectives into the multiple-use planning and management framework.

VISUAL IMPACT ASSESSMENT

Visual impact assessment in the VMS process uses indirect measures such as Visual Absorption Capability or in the BLM method, contrast ratings. These measures may imply the direction of impacts on visual quality, but no attempt is made to predict the magnitude of change in scenic beauty. The VIAM method provides a powerful, integrated system for more precise and efficient visual impact assessment. Impacts on scenic beauty are modelled directly from measured or projected changes in relevant themes in the spatial data base. These changes may represent effects of proposed management activities developed in the plan formulation process, or natural occurrences such as forest fires or insect damage. Scenic beauty is modelled for specific viewpoints, giving the manager a more precise assessment and more flexible options for mitigating visual impacts.

An important part of the interactive approach to modelling visual impact is the ability to request visual simulations of impacts directly from the GIS data base. "Before" and "after" views may be requested, or representations of visual effects as seen from different viewer positions can be generated. The VIAM also provides the manager with statistical summaries of the size of the impact, and the predicted change in public perception of scenic beauty for each view.

BIBLIOGRAPHY

Brown, T.C. and T.C. Daniel (1984) Modeling Forest Scenic Beauty: Concepts and Application to Ponderosa Pine. USDA Forest Service Research Paper RM-256, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Brown, T.J. and R.M. Itami (1982) "Landscape Principles Study: Procedures for Landscape Assessment and Management-Australia", Landscape Journal, 1:Fall pp.113-121

Buhyoff, G.J. and J.D. Wellman (1980) "The Specification of a Non-Linear Psychophysical Function for Visual Landscape Dimensions", Journal of Leisure Research, Vol. 12:3 pp. 257-272

Buhyoff, G.J., J.D. Wellman and T.C. Daniel (1982) "Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas". Forest Science 25:837-838.

Buhyoff, G.J., L.K. Arndt, and D.B. Propst (1981) "Interval scaling of Landscape Preference by Direct and Indirect Measurement Methods", Landscape Planning. vol. 8: pp. 257-267

Craik, K.H. and N.R. Feimer (1979) "Setting Technical Standards for Visual Assessment Procedures" in Proceedings of Our National

Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource. G.H. Elsner and R.C. Smardon technical coordinators, USDA Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-35, Berkeley, CA.

Daniel, T.C. and R.S. Boster (1976) Measuring Landscape Esthetics: The Scenic Beauty Estimation Method. USDA Forest Service Research Paper Rm-167. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Daniel, T.C. and H. Schroeder (1979) "Scenic Beauty Estimation Model: Predicting Perceived Beauty of Forest Landscapes " in Proceedings of Our National Landscape: A Conference on Applied Techniques for Analysis and Management of the Visual Resource. G.H. Elsner and R.C. Smardon technical coordinators, USDA Pacific Southwest Forest and Range Experiment Station, General Technical Report PSW-35, Berkeley, CA.

Daniel, T.C., W.B. White, and D.O. Hunter (1984) Integrated Pest Impact Assessment System: An Interface to a Forest Management Information System USDA Forest Service. FPM/MAG Report No. 84-2, Fort Collins, CO.

Daniel, T.C. and J. Vining (1983) "Methodological Issues in the Assessment of Landscape Quality", in: I. Altman and J.F. Wohlwill (Editors), Human Behavior and Environment Vol 6.. Plenum Press, New York, pp. 39-84

Daniel, T.C. and E.H. Zube (1979) "Assessment of Esthetic Resources", Assessing amenity resource values. USDA Forest Service General Technical Report RM-68, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Feimer, N.R., R.C. Smardon and K.H. Craik (1981) "Evaluating the Effectiveness of Observer Based Visual Resource and Impact Assessment Methods", Landscape Research. Vol. 6:1 pp. 12-16

Gimblett, H.R., R.M. Itami, J.E. Fitzgibbon (1985) "Mystery in an Information Processing Model of Landscape Preference", Landscape Journal , University of Wisconsin Press, Ann Arbor, Michigan

Itami, R.M. (In Press) "Scenic Perception: Research and Application in U.S. Visual Management Systems" in Canadian Western Geographic Series. P. Dearden, Editor, University of Victoria, Canada.

Kopka, S. and M. Ross (1984) "A Study of the Reliability of the Bureau of Land Management Visual Resource Assessment Scheme", Landscape Planning. Elsevier Science Publishers, Amsterdam, Vol 11 pp. 161-166

Laughlin, N.A. (1984) "Attitudes of Landscape Architects in the USDA Forest Service Toward the Visual Management System" unpublished MLA thesis, School of Renewable Natural Resources, University of Arizona,

Tucson, AZ.

Miller, P.A. (1984) "A Comparative Study of the BLM Scenic Quality Rating Procedure and Landscape Preference Dimensions", Landscape Journal, Vol. 3:2 pp.123-135

Myklestad, Eric and J.Wager (1976) "PREVIEW: Computer Assistance for Visual Management of Forested Landscapes," Research Paper NE-355, 1976, USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA.

Porteous, D. (1982) "Approaches to Environmental Aesthetics", Journal of Environmental Psychology, Academic Press Inc., London, Vol 2: pp. 53-66

Schroeder, H.W. and T.C. Brown (1983) "Alternative Functional Forms for an Inventory-Based Landscape Perception Model", Journal of Leisure Research. National Recreation and Park Association. Vol 15:2 pp. 156-163

Sheppard, Stephen R.J. (1985) "Illustrating Future Landscapes: A User's Guide to Visual Simulation" unpublished manuscript.

Smardon, R.C., N.R. Feimer, K.H. Craik, and S.R.J. Sheppard (1983) "Assessing the Reliability, Validity and Generalizability of Observer-Based Visual Impact Assessment Methods for the Western United States", in Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas R.D. Rowe and L.G. Chestnut (eds), Westview Press, Boulder, Colorado pp 84-101

Travis, M.R., G.H. Elsner, W.D. Iverson, and C. Johnson (1975) "VIEWIT: Computation of seen areas, slope, and aspect for land-use planning." Technical Report PSW-11/1975, USDA Forest Service, Berkeley, CA.

Twito, Roger and J.Warner (no date) "Perspective Plot Program for Evaluating Visual Impact of Proposed Timber Harvest Units with Desktop Calculator, Plotter and Digitizer" USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

USDI Bureau of Land Management (1980a) Visual Resource Management Program BLM Division of Recreation and Cultural Resources, Washington D.C.

USDI Bureau of Land Management (1980b) Visual Simulation Techniques BLM Division of Recreation and Cultural Resources, Washington D.C.

USDI Bureau of Land Management (1984) "8400 - Visual Resource Management" (revision, release 8-24), Washington, D.C.

USDA Forest Service (1974) National Forest Landscape Management, Volume 2, chapter 1 The Visual Management System, Agriculture

Handbook Number 462, Washington, D.C.

Zube, E.H., J.L. Sell and J. G. Taylor (1982) "Landscape Perception: Research, Application, and Theory", Landscape Planning. Vol 9:1 pp. 1-33

DECISION AID FOR IPIAS--PROPOSAL

MULTIPLE ATTRIBUTE UTILITY THEORY

DECISION AID FOR IPIAS

The Multi-Objective Decision Aid (MODA) proposed for IPIAS would be a computer implemented module for comparing and evaluating large numbers of management alternatives that differ on multiple non-commensurate criterion dimensions. The purpose of MODA is not to algorithmically select the "best" or "optimum" alternative, rather the goal is to provide preferability rankings of alternatives based on trade-offs among multiple criteria given user specified value (importance) structures. The Integrated Forest Resource Management System projects estimates of various economic, environmental and social benefits and costs for each management alternative. These alternative-by-criterion output arrays, combined with user provided importance weights (or value structures), are used to provide descriptive evaluations (pay-off matrices) for all alternatives over all criteria, pair-wise or multiple comparisons to reduce the set of alternatives and/or criteria, or analyses to produce complete rankings/preferability mappings of all alternatives.

Sample output is presented from an example application to a forest management decision problem in the southwest. A micro-computer implemeted version the system "EXPERT CHOICE" was used to evaluate six management alternatives over a hierarchically arranged set of resource goals/outputs.

DECISION PROBLEM BACKGROUND

The decision problem is to choose a plan for managing public forest lands in the Southwestern U.S. Initially, you will not be given the actual alternatives, but will give your relative preferences for the attributes on which the alternatives will be judged. When making judgements, you may want project a Sierra Club or James Watt attitude, or you may give your own preferences. It is important, however, that you maintain consistency in your attitudes throughout the exercise.

The alternatives presented in the problem adhere to the issues of concern to varying degrees. They propose different strategies for managing the lands and resources of the Forest. Each alternative is a unique combination of management prescriptions applied to the land. Consequently, each would generate a different mix of goods and services for the public, and a different combination of resource outputs, land uses, and environmental effects.

Some of the alternatives emphasize a balanced mix of management actions, while others lean more toward one specific set of concerns, like economic efficiency, environmental protection, and production of recreation and livestock. They are sufficiently different from each other so that distinct decision maker preference structures will lead to different rankings of the alternatives' desirability.

The hierarchy of objectives and attributes is provided on the following page.

The objectives are:

Recreational - provide the public with various recreational opportunities.

Environmental - promote conservation of natural resources. In general (but not always), environmental objectives conflict with recreational and socio-eonomic objectives.

Socio-Economic - reap monetary, as well a social (provide jobs, help the cattle industry, etc.) benefits. Socio-economic benefits are measured in dollars and indicate not only absolute revenues, but the level of land use and corresponding social benefits.

The attributes (and their units of measurement) are:

Developed Recreation (percent of public demand satisfied) - includes campgrounds, picnic areas, resorts and lodges, winter sports areas, etc.

Dispersed Recreation (percent of public demand satisfied) - includes hiking, backpacking, camping, hunting, fishing, rock climbing, etc.

Off-Road Vehicle (ORV) Use (percent of land open to ORV use) - "open" to ORV use includes not only designated roads and trails, but also backcountry.

Threatened and Endangered Species Habitat (percent of existing amount) - includes species which are in danger of extinction throughout all or a significant portion of its range (e.g., Mount Graham Red Squirrel, Mexican Wolf, Jaguar, Bald Eagle, Peregrin Falcon).

Riparian Habitat (percent of existing amount) - surrounding stream banks, lake shorelines, and flood plains of streams and wetlands. Have high biological productivity.

Game Species Habitat (percent of existing amount) - game species include big game (e.g., deer and bear) normally managed as a hunting resource and small game (birds and small mammals) normally hunted or trapped.

Watershed Condition (number of acres in satisfactory condition) - watershed acreage in satisfactory condition is a description of hydrologic function and soil productivity. Major problems with watersheds include sedimentation and decline in water quality and soil productivity due to erosion.

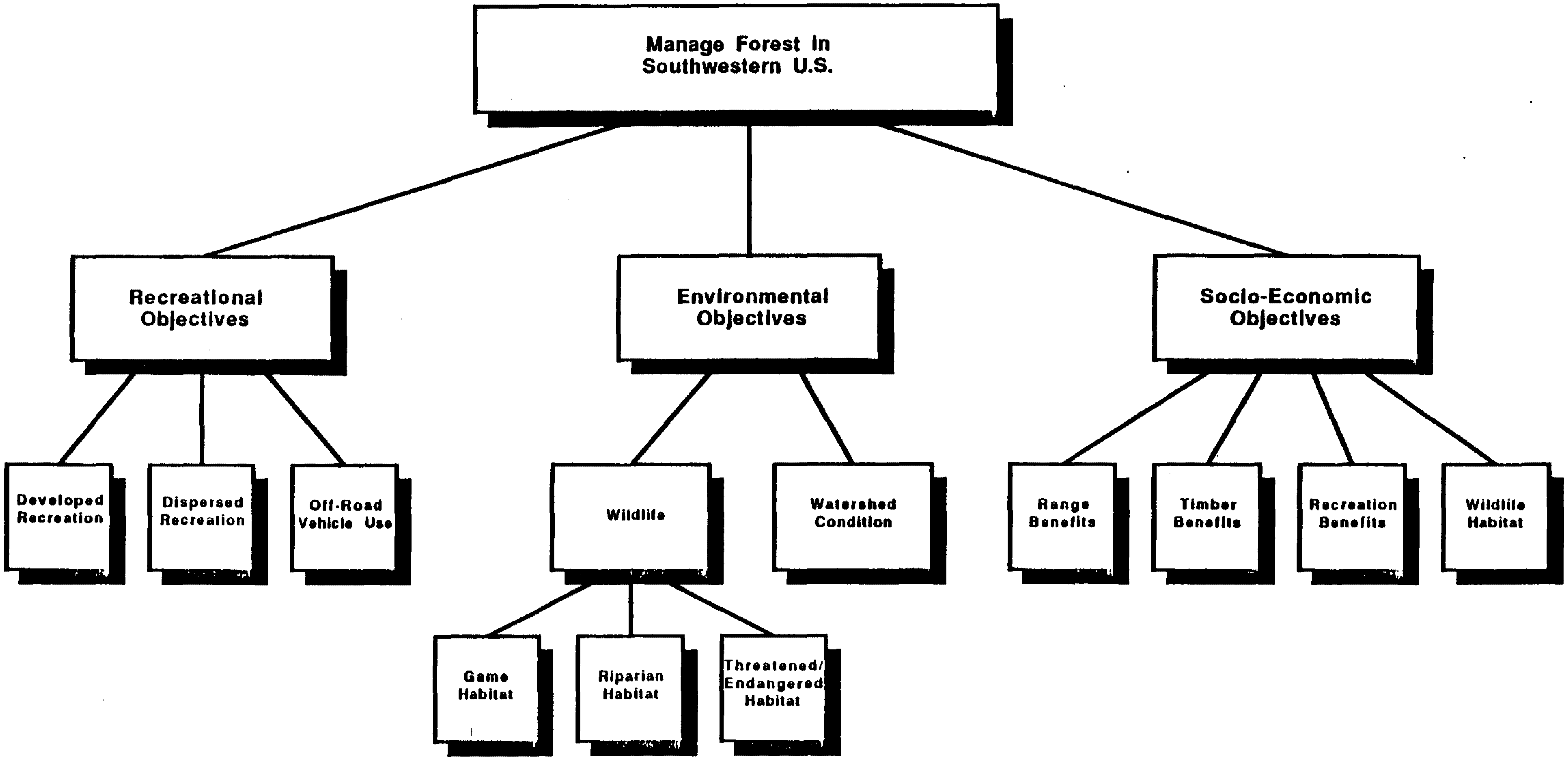
Range Benefits (thousands of dollars) - benefits generated from grazing permits

Timber and Fuelwood Benefits (thousands of dollars) - benefits generated from sawtimber and wood harvesting permits

Recreational Benefits (thousands of dollars) - benefits generated from campgrounds, ORV permits, etc.

Wildlife Benefits (thousands of dollars) - benefits generated from big game, small game, and fishing use.

DECISION PROBLEM STRUCTURE



DIRECT RANKING OF ALTERNATIVES

The data for the six management alternatives under consideration are provided below. Rank the desirability of the alternatives in the space provided. Include any comments regarding your relative strength of preference.

ATTRIBUTES (Units)	ALTERNATIVES A	B	C	D	E	F
DEVELOPED REC (% Demand Sat)	85	74	61	42	68	68
DISPERSED REC (% Demand Sat)	72	85	63	79	76	78
ORV USE (% Demand Sat)	73	56	24	0	29	18
GAME HABITAT (% of Existing)	97	102	112	116	109	105
RIPARIAN HABITAT (% of Existing)	87	90	93	117	105	109
T/E HABITAT (% of Existing)	93	96	97	112	106	110
WATERSHED CONDITION (Acres Satisfactory)	1102	1231	1318	1706	1384	1373
RANGE BENEFITS ($1000)	4556	3631	6043	2992	4639	4311
TIMBER BENEFITS ($1000)	108	55	183	23	77	89
RECREATION BENEFITS ($1000)	39000	39000	36000	17000	36000	24000
WILDLIFE BENEFITS ($1000)	7100	7400	8200	11300	9800	8200

COMMENTS: ____

MANAGE FOREST IN SOUTHWESTERN U.S.

```
                         ----------
                         !  GOAL  !
                         !        !
                         ! L 1.000!
                         ----------
                              !
                   -----------------------
                   !          !          !
             ---------- ---------- ----------
             !RECREAT.! !ENVIRON.! !SOC-ECON!
             !        ! !        ! !        !
             ! L 0.333! ! L 0.592! ! L 0.075!
             ---------- ---------- ----------
             !-DEV REC  !-WILDLIFE !-RANGE
             ! L 0.352  ! L 0.600  ! L 0.221
             !-DISP REC !-WATERSHD !-TIMBER
             ! L 0.552  ! L 0.400  ! L 0.063
             !-ORV USE             !-REC BEN
             ! L 0.096             ! L 0.510
                                   !-WILD BEN
                                   ! L 0.206
```

```
  GOAL    --- MANAGE FOREST IN SOUTHWESTERN U.S.
DEV REC   --- DEVELOPED RECREATION
DISP REC  --- DISPERSED RECREATION
ENVIRON.  --- ENVIRONMENTAL OBJECTIVES
ORV USE   --- OFF ROAD VEHICLE USE
RANGE     --- RANGE BENEFITS
REC BEN   --- RECREATION BENEFITS
RECREAT.  --- RECREATIONAL OBJECTIVES
SOC-ECON  --- SOCIO-ECONOMIC OBJECTIVES
TIMBER    --- TIMBER BENEFITS
WATERSHD  --- WATERSHED
WILD BEN  --- WILDLIFE BENEFITS
WILDLIFE  --- WILDLIFE

L         --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

```
                          0
                          !
                     -----!-----
                     0    0    0
                               !
              -----------------!-------------------------
              !                !                 !    !

              0         !TIMBER   !        0    0
                        !         !
                        ! L 0.063!
                        ----------
                               !
  --------------------------------------------------------------------------------
  !              !              !              !              !              !
----------   ----------   ----------   ----------   ----------   ----------
!A        !  !B        !  !C        !  !D        !  !E        !  !F        !
!         !  !         !  !         !  !         !  !         !  !         !
! L 0.202!  ! L 0.103!  ! L 0.342!  ! L 0.043!  ! L 0.144!  ! L 0.166!
----------   ----------   ----------   ----------   ----------   ----------
```

```
A           --- A
B           --- B
C           --- C
D           --- D
E           --- E
F           --- F
TIMBER      --- TIMBER BENEFITS

L           --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

```
                          O
                          !
         -----------------+-----
         !   !            !

         O   O       -----------
                     !SOC-ECON!
                     !        !
                     ! L 0.075!
                     -----------
                          !
    ----------------------------------------------------
    !                !                !                !
---------- ---------- ---------- ----------
!RANGE    ! !TIMBER   ! !REC BEN ! !WILD BEN!
!         ! !         ! !        ! !        !
! L 0.221! ! L 0.063! ! L 0.510! ! L 0.206!
---------- ---------- ---------- ----------
!-A        !-A        !-A        !-A
! L 0.174  ! L 0.202  ! L 0.204  ! L 0.137
!-B        !-B        !-B        !-B
! L 0.139  ! L 0.103  ! L 0.204  ! L 0.142
!-C        !-C        !-C        !-C
! L 0.231  ! L 0.342  ! L 0.188  ! L 0.158
!-D        !-D        !-D        !-D
! L 0.114  ! L 0.043  ! L 0.089  ! L 0.217
!-E        !-E        !-E        !-E
! L 0.177  ! L 0.144  ! L 0.188  ! L 0.188
!-F        !-F        !-F        !-F
! L 0.165  ! L 0.166  ! L 0.126  ! L 0.158
```

```
A          --- A
B          --- B
C          --- C
D          --- D
E          --- E
F          --- F
RANGE      --- RANGE BENEFITS
REC BEN    --- RECREATION BENEFITS
SOC-ECON   --- SOCIO-ECONOMIC OBJECTIVES
TIMBER     --- TIMBER BENEFITS
WILD BEN   --- WILDLIFE BENEFITS

L          --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
```

```
                    GOAL: MANAGE FOREST IN SOUTHWESTERN U.S.

                                With respect to
                                RECREAT. < GOAL

DISP REC :DISPERSED RECREATION
  is MODERATELY MORE IMPORTANT THAN
DEV REC  :DEVELOPED RECREATION

                    -------------------------------------
                    !                                   !
                    ! EXTREME-----------                !
                    !                                   !
                    ! VERY STRONG-------                !
                    !                                   !
                    ! STRONG------------                !
                    !                                   !
                    ! MODERATE----------  <--           !
                    !                                   !
                    ! EQUAL-------------                !
                    !                                   !
                    !                                   !
                    -------------------------------------
```

Appendix A

Publications Produced

United States
Department of
Agriculture

Forest
Service

**Forest Pest
Management**

**Methods
Application
Group**

Fort Collins,
Colorado 80524

INTEGRATED PEST IMPACT ASSESSMENT SYSTEM DEVELOPMENT: IMPACT MODEL INVENTORY AND USE SURVEY

Report No. 86-5

3400
June 1986

INTEGRATED PEST IMPACT ASSESSMENT SYSTEM DEVELOPMENT: IMPACT MODEL INVENTORY AND USE SURVEY[1/]

by

G.J. Buhyoff, T.C. Daniel, W.B. White, and D.O. Hunter[2/]

ABSTRACT

The first phase of the development of an expanded Integrated Pest Impact Assessment System (IPIAS) was an inventory of forest stand, pest and other forest resource impact models. Models were evaluated for their applicability to the IPIAS concept in which models would be linked to provide management information about predicted impacts of forest pests. A survey of potential users of IPIAS was conducted in conjunction with this inventory. This survey solicited opinions about current impact model use as well as future model needs. Results of these efforts indicate both a need for IPIAS and the existence of a potentially useful base of models for development of IPIAS.

INTRODUCTION

The development of an expanded Integrated Pest Impact Assessment System (IPIAS) is to be accomplished over a period of several years (Daniel et al. 1983). The goal of IPIAS is to provide forest planners and managers with an efficient and effective means for projecting the socioeconomic and biological impacts of pest outbreaks and alternative management actions designed to reduce losses. The system will not only focus upon the effects of forest changes associated with pest damage and control, but will also be applicable

---

1/The work described herein was funded in whole or in part by USDA Forest Service, Forest Pest Mangement/Methods Application Group, as part of a five year project - Integrated Pest Impact Assessment System (IPIAS). Cooperative Research Agreement (No. 28-C4-320) between Rocky Mountain Forest and Range Experiment Station for MAG, and Virginia Polytechnic Institute and State University, details the specific objectives and funding for this project.

2/The authors are respectively: Professor of Biometrics, Virginia Polytechnic Institute and State University, Blacksburg, VA; Professor of Psychology and Renewable Natural Resources, University of Arizona, Tucson, AZ; Entomologist, USDA Forest Service, Forest Pest Management/Methods Application Group, Fort Collins, CO; and Ecologist, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, CO.

to a much wider range of forest management problems (actions which cause stand modification).

A major project objective is to enhance IPIAS with a geographic information system (GIS) which would serve as the input data base for stand growth and impact models. The geographic information system should allow the user to quickly input specific stand data and area and spatially evaluate the current resource. IPIAS, then, will for several time periods, take one initial stand, modify it by way of a growth simulator model, a pest outbreak model, and a given management prescription and then output the characteristics of the residual stand at each time period. These data can then be used as inputs to impact models of various types.

OBJECTIVES

A logical starting point in the development of such a system is the identification of currently available pest impact models and the assessment of user opinions of these and other related models. In fact, a 5-year research and development project for IPIAS (Anonymous 1983) charts a course of action which includes these tasks. Some of the major areas of development specified by this document are: (1) survey and evaluate models now in use, and (2) identify model information currently used and additional information needs. More specifically, a cooperative research agreement (No. 28-C4-320) with Virginia Polytechnic Institute and State University and the University of Arizona specified that the following detailed objectives were to be accomplished in Fiscal Year 1984 as the first stage of IPIAS development:

1. Conduct a search for forest stand and socioeconomic impact models.

2. Conduct a search for mountain pine beetle models.

3. Survey pest management and research groups for mountain pine beetle models currently being used or developed.

4. Report on existing forest stand and mountain pine beetle models, including types of data needed and types of output produced.

5. Identify potential users of IPIAS.

6. Identify impact information currently used by these groups and how it is used.

7. Identify additional information user groups would like to have.

MODEL INVENTORY AND ASSESSMENT

To develop a solid basis for the extension of IPIAS, a comprehensive evaluation was conducted (Appendix A) of currently available pest impact and other forest prediction models which might be candidates for IPIAS application

in targeted demonstration areas (USDA Forest Service Regions 1 and 6). Models were identified and evaluative criteria developed based on intensive interviews with Forest Service personnel in the Washington Office, Forest Research Stations, and Region 1 and 6 staffs. A total of 55 individuals, all familiar with the development and use of models for forest management and planning, were contacted in this model evaluation phase. As a result, 46 separate models or model extensions were identified and evaluated for their potential usefulness to IPIAS and were entered into a computer data base management system for quick reference and update. Documentation was obtained for these models and where necessary, individuals who could clarify model use were contacted. Thirty-one of the models were deemed as meeting the broad criteria of either generalized applicability to Regions 1 or 6, or applicability to lodgepole pine (Table 1). These models also had to be useful in assessing impacts as the result of mountain pine beetle infestations or in making predictions regarding the behavior of such infestations.[3/] The models did not have to be applicable to all four criteria. This was not merely a literature search since the total effort described here included analysis of the models as to their applicability to IPIAS as well as an evaluation of each models potential interfaceability to a broader network of impact models as required by IPIAS. Each of the models were evaluated for application region, stand and species type, input data requirements, output data requirements, limitations and constraints, extensions and modifications, and indications of validity testing.

The remainder of the 46 models were also comprehensively evaluated but not included in the data base since their applicability to IPIAS was determined to be minimal or nonexistent because their primary use was in places other than Regions 1 or 6. These included: INVEST III, MULTIPLOY, Budworm Evaluation Model, MTVEST, MAX2, RAMPREP, ECHO, SIMAC, and SORAC. In addition to the 46 models, 32 other trend prediction, management simulation, hazard rating, and spot growth models specific to southern pine beetle were researched and assessed as to their potential applicability to IPIAS (Table 2). These models are summarized in Mason (1984). Again, these models were, however, not directly applicable to the development of IPIAS in Regions 1 and 6. During this model identification phase, several other quantitative impact models were found. However, these models were discovered to be "only guidelines", "under development", "not tested", "currently being debugged", "not widely applicable", or in some cases, only rumored and did not actually exist. The final 31 models which were selected as being potentially useable in IPIAS can be broken down into categories for which they make predictions, conduct efficiency analyses, or perform simulations (Table 1). The categorizations in Table 1 are one way of assessing prevalence or absence of certain types of models. Note that some models appear under more than one category since they perform more than one type of prediction or analysis.

[3/]Copies of this data can be obtained by writing G.J. Buhyoff, Professor of Forest Biometrics, School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Table 1 - Models Evaluated for use in IPIAS.

Growth and Yield	Insect/Pest	Economic Efficiency
PROGNOSIS	Dwarf Mistletoe	CHEAPO
TRAS	Mountain Pine Beetle	FORESTRY INVESTMENT ANALYSIS
FREP/STEMS	TREE LOSS FROM MOUNTAIN	TRIM
TWIGS	PINE BEETLE INFESTATIONS	DPDFSIM
TRIM	INDIDS	LP-DM-VOL
ECOSIM	LP-DM-VOL	
GROW	PROGNOSIS extensions:	
DFSIM	Western Spruce Budworm	
INDIDS	Douglas-Fir Tussock Moth	
TREES		
R2GROW		
RMYLD		
Harvest Scheduling	**Wildlife**	**Hydrology**
TREES	ECOSIM	ECOSIM
PROGNOSIS extension:	PROGNOSIS extension:	SREAM SEDIMENTATION
EVENT MONITOR	COVER HABITAT SUITABILITY	(Effects on Salmond Habitat)
	INDEX MODELS	
	ELK HABITAT MODEL	
Economic-Input/Output	**Debris**	**Comprehensive Simulations**
IMPLAN	DEBMOD	ECOSIM
MICRO I/O		

It is particularly noteworthy that no range, recreation use, or visual quality models are listed. Current approaches to the assessment of impacts on "other" forest resources such as social impacts tend to be more qualitative than quantitative and rely on expert judgment rather than explicit analytical systems despite the fact that the technology exists to formulate such models.

The wildlife category displays models which can aid wildlife impact predictions; however, one is specifically incorporated in the ECOSIM model itself and another (PROGNOSIS, COVER extension) makes projections of changes in shrubs and canopy which can potentially be used as input for specific wildlife population models. A single quantitative model for the prediction of elk movement was found for the target regions. Also, a comprehensive set of wildlife "impacts" developed by the Western Energy and Land Use Team (WELUT) of the U.S. Fish and Wildlife Service, were also identified. These models,

Table 2 - Southern pine beetle prediction models evaluated for possible integration with IPIAS[1]

Trend Prediction Models	Hazard Rating Models
SPB COMP	TFS GRID HAZARD
AERIAL GA	AR HAZARD
SOUTHEAST SURVEIL	MS HAZARD B
SOUTHEAST PREDICT	SADER HAZARD
NC SURVEIL	P HAZARD GA
NC PREDICT	TX HAZARD
NC PIED SURVEIL	WEST GULF HAZARD
NC PIED PREDICT	NF RISK
GA SURVEIL	PIEDMONT RISK
GA PREDICT	MOUNTAIN RISK
FRONSIM	WEST GULF PROB
DAMBUGS	COAST PROB
	PIED PROB

Management Simulation Models	Spot Growth Models
CLEMBEETLE	TAMBEETLE
	ARKANSAS SPB
	TFS SPOT GROWTH
	EA Ratio

[1]From Mason (1984; revised June).

referred to as Habitat Suitability Index (HSI) models, project impacts on wildlife and fisheries species by predicting habitat suitability (as an 0-1 index) resulting from changes in that habitat. These HSI models appear to be of the type suitable for IPIAS. From our research it seems that "rules of thumb" are more prevalent than mathematical formulations for making predictions of changes in wildlife levels. For example, Thomas (1979) details many descriptions of habitat types which support various bird and wildlife species.

USE OF MODELS IN IPIAS

The models presented in Table 1 are representative of model components that might be used in Region 1 or 6 IPIAS. IPIAS is not intended to be a single set of models to be used in all locations or situations. Rather, IPIAS is intended to be a framework for a computer assisted forest pest management information system that can link together (1) biological (including forest

growth and mortality, yield, and pest effects); (2) economic (stumpage values, management costs, and local and regional economic effects); and (3) social impact (recreation, scenic beauty, and wildlife) components. IPIAS will provide information assimilation and presentation rather than optimization. It is not, by itself, a decisionmaking system. Because of its modular design and its use of forest characteristics as a basic input to all impact modeling IPIAS can be used to address a wide range of forest management problems for a specific application area (a major drainage). Thus, the comprehensive model inventory and evaluation presented here and in Buhyoff and Daniel (1984) provides information necessary for determining what components can be "pulled off the shelf" to be linked into IPIAS for a particular geographic forest management unit application.

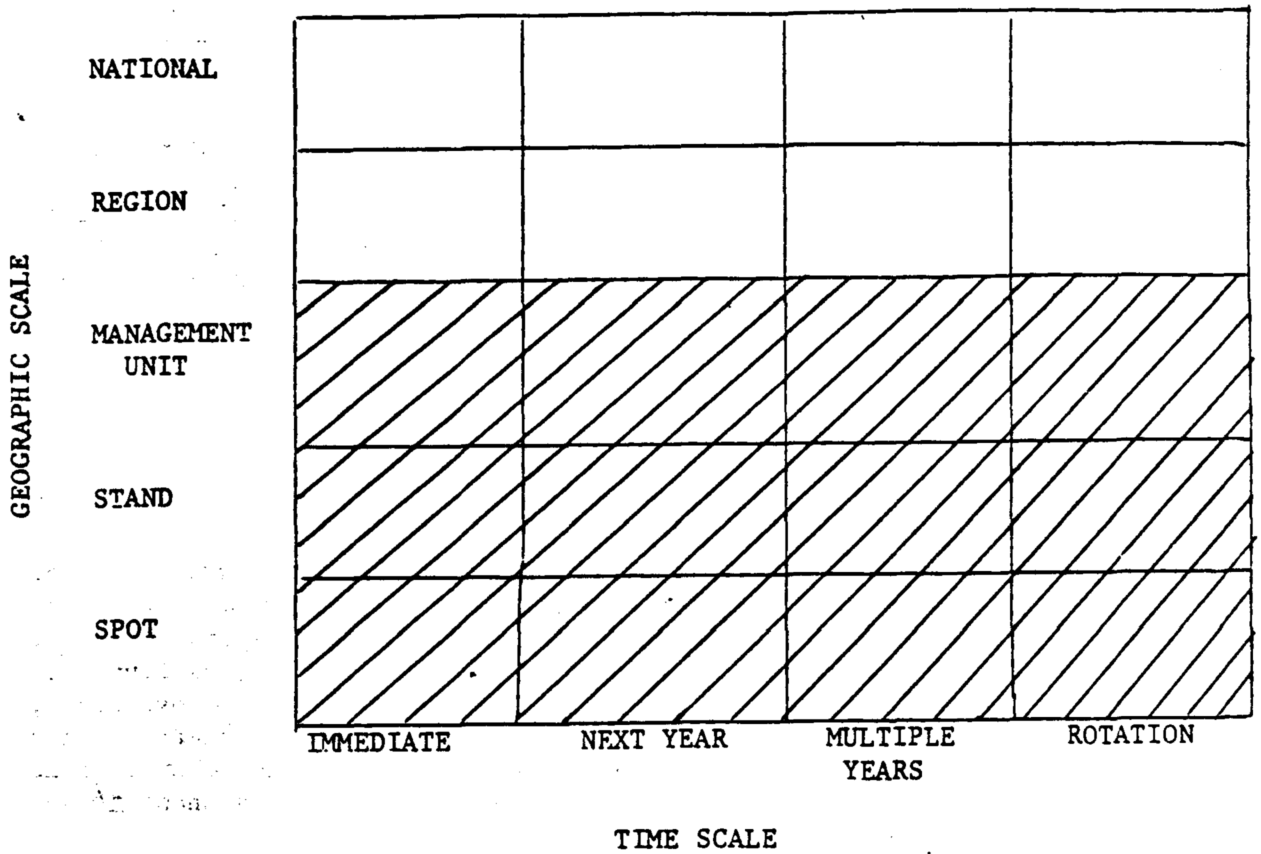
At this stage of the IPIAS development program it is difficult to further define the exact linkages and use of the models in IPIAS. While it is obvious that growth and yield models are different in their inputs/outputs from economic efficiency and other models, ultimate use of any of these models and the resultant use of them by IPIAS can only be meaningful given specific user needs. At the simplest level they are all prediction techniques; however, while we know they predict different parameters, they also do so in different ways. Some of the models listed are simulations, others are optimization models. Also, they make predictions over different time frames, geographical areas and for different stand types. Since the primary intent of IPIAS is to be a management information rather than a management decision system, the basic IPIAS framework will not ordinarily provide linkages to <u>optimization</u> models but only to <u>impact</u> models. However, should a set of users wish optimization model linkages, these can be defined and constructed.

The question of geographic scale of the predictions is also critically involved in evaluating similarity of different models functional capabilities for IPIAS. For example, TAMM and TRIM are aimed at Resource Planning Act (RPA) type assessments, primarily on a national scale. IMPLAN uses counties as the smallest projection unit. PROGNOSIS predictions can be accomplished for a single stand or a group of stands; thus, it should be possible to construct IPIAS packages of different area scales.

Related to the question of the area scale for impact predictions is the question of deciding the use of or time frame for IPIAS predictions. IPIAS will probably be used to plan or schedule, for example; suppression activities, budget requests, field activities, and short or long term management regimes. Uses, then, define the time scale of the total scope of IPIAS.

The Integrated Pest Management Program for Southern Pine Beetle has suggested a manner in which to categorize prediction models (Leuschner 1979; Mason 1984). They suggest that all models be considered within a matrix defined by the interaction of time and area. This matrix (Figure 1) provides not only a means of categorizing models, but also a framework for making decisions about what an integrated impact system <u>should include</u>. In our view the scope of IPIAS is most likely represented by the cross-hatched cells of the matrix in Figure 1. Obviously the time frame of prediction is related to the ultimate <u>use</u> of these predictions in a specific application area (e.g., stand level suppression activities versus watershed silvicultural prescriptions).

Figure 1 - Temporal and spatial scale matrix with which to categorize prediction models for their applicability in an integrated impact assessment system[1/].



Cross-hatched cells - models addressing these temporal and spatial criteria were considered appropriate for inclusion in IPIAS. Conversely, the cross-hatched cells also indicate the most probable location for IPIAS implementation.

[1/]From Leuschner (1979) and Mason (1984).

If benefit/cost analysis is to be ultimately used as a decision criterion for assessing the impacts of a control program for pests, then those models which afford the opportunity to integrate their outputs into benefit/cost analyses could be linked together as potential components of a particular operationalization of IPIAS. If, on the other hand, only general impact tradeoffs are to be assessed, then another different set of models can be linked together.

The process by which these models can be accessed by users and linked together in order to solve pest impact problems across a broad range of geographic and time requirements is problematic. However, the Southern Pine Beetle Decision Support System (SPBDSS) is an example of one way to accomplish this task (Rykiel et al. 1984). The Decision Support System (DSS) is an interactive computer program which acts as an operating "shell" or executive

program to manage a library of models and information about them. This system can aid the user in defining the nature of his pest problem and can recommend predictive models to use in the problem solution (subprogram called FERRET). Further, it can automatically link appropriate models and coordinate the execution of them to provide comprehensive impact output. This DSS, or one similar to it, may well provide the basic operating framework for IPIAS.

During Fiscal Year 1985 a version of IPIAS was designed for the Red River District of the Nezperce National Forest in Idaho. This IPIAS includes a growth and yield simulator (PROGNOSIS), a mountain pine beetle contagion model, an elk migration model based upon habitat changes, a stream sedimentation model, and a fish habitat model. The entire IPIAS for this application area is driven from the geographic information system MOSS. This system was installed on the Forest's Data General minicomputer during July 1985.

CURRENT MODEL USE AND NEEDS

A survey was designed to assess user characteristics, the need for pest impact models, and model interface requirements. This questionnaire was sent to 255 individuals in Forest Service Regions 1 and 6. Each regional office, forest, and district were sent copies of the questionnaire. Questionnaires were also sent to specialists in timber management, recreation, hydrology, planning, wildlife, silviculture, and pest management. The intent of the questionnaire was to not only assess user interface needs, but also to find other models which were not discovered during the model inventory phase.[4/]

A total of 62 completed survey responses were returned. In a number of cases, one respondent represented the model use/needs of several individuals, i.e., survey recipients tended to pass the questionnaire on to their "resident model user". While the distribution list for the survey was comprehensive, there was no way to assure a complete return. Thus, the "representativeness" of the respondents is to some extent unknown, and there may be models and/or users in the targeted regions that were not captured by this survey.

The geographic distribution of survey respondents indicated good coverage of Regions 1 and 6. District, forest, and regional levels were all represented; not surprisingly, the large majority of respondents were silvicultural specialists. The low response rate from other forest specialists is consistent with the lack of available models for wildlife, recreation, or aesthetics, that was reported above.

While every effort was made to survey all models and model users in Regions 1 and 6, there is no guarantee that every model or model use problem was identified. In combination, however, the direct interviews with knowledgeable individuals, the survey of model developers and expert users in both target

---

[4/]Detailed results of this user survey of model use and needs can be obtained by writing to Dr. G.J. Buhyoff, Professor of Forest Biometrics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

regions; and the responses to the mailed survey provide a consistent and comprehensive profile of model use in forest management and planning. Again, a number of the "models" that were reported (or even rumored) to be in use were investigated and found to be, for example, either only "guidelines", not widely applicable, or not documented for general use. These were not included in this analysis which focused upon documented models which were, at least in principle, available for general use and which had been implemented.

It was very clear from this survey that the principal use of models in the target regions is for timber management. Forest silvicultural specialists far outnumber all other model users and "growth and yield" models are the most available, most used, and most sophisticated of the models identified by the survey. Indeed, as noted before, the use of models for wildlife, recreation, scenic quality, and range and water appears to be negligible or nonexistent. While some successful models have been developed in these areas (Buhyoff et al. 1982; Schroeder and Daniel 1981), they are apparently not well known in these regions, and are currently not in use. Even in forest economics, where quantitative analysis and computer modeling has a more extensive history, little use of models was reported. Pest management reported substantial impact model use, but this was principally in very close relation to timber management activities.

PROGNOSIS and, to a much lesser extent, DFSIM, both growth and yield simulators, were the dominant models used in Regions 1 and 6. Users of PROGNOSIS outnumbered the users of all other models by a wide margin. Again, this is due to the fact that PROGNOSIS has wide species and geographic application. User confidence in PROGNOSIS was generally high, though many users cited the need for improving the accuracy by better calibration to local conditions. At the same time, the relatively wide range of application was recognized as a strength, and there were several calls for an even greater range of application. In this context, the need for a less demanding, more user friendly interfact to PROGNOSIS, a concern cited by a number of users, becomes especially critical. The challenge to PROGNOSIS and other models for this user group is to provide the desired generality <u>and</u> local accuracy without introducing excessive input data requirements or mandating high computer sophistication on the part of the user.

Integration between models and data bases appears to be at a low level. There is some linkages between PROGNOSIS and one or another version of the standard forest inventory data bases. Linkages to geographic information systems are not presently available except where users have invented their own systems as such. Linkages among models in use is essentially nonexistent except for the PROGNOSIS extension models which are directly tied to the main PROGNOSIS growth and yield module. The most comprehensive effort at model linkage is represented by ECOSIM (a general ecosystem simulator), but this system is not generally available and essentially no use was reported in Regions 1 and 6. Once again, respondents requests for improved user interface are relevant. Effective integration of models and data bases could reduce the need for repetitive and redundant data entry, parameter specifications and input/output control formats.

Most users felt that the costs of model use were reasonable, and virtually all agreed that costs were outweighed by benefits. Indications are that model

projections are substantially influential in forest planning and management, and they may be even more so in the future. In this context, the essential lack and nonuse of systematic models for representing impacts on wildlife, scenic quality, recreation, and other social and socioeconomic concerns necessarily implies rather low potential for these "other forest resources" to influence forest planning and management. Social impact models, or at least methods for developing such models, are available. Thus, this imbalance, which may be inconsistent with a number of public land management policies and regulations, need not continue. Survey results indicate, however, that there is little knowledge of the existing social impact models, little acknowledgement of the need for such models (except perhaps for wildlife), and in a few instances, outright antagonism toward the concept of modeling scenic or recreation values.

This survey of model use provides a basis for characterizing contemporary forest planning and management, at least as represented by Regions 1 and 6. The use of computer implemented models of forest growth and mortality is intensive, widespread, and increasing for timber management and related pest management concerns. The influence of model projections on the formulation and selection of forest management alternatives is currently substantial, and promises to increase, especially given the growing availability of the computer hardware that is required for efficient use of these models. This scenario provides substantial impetus for the parallel development of systematic, computer implemented models to represent other forest management concerns. In this regard, Forest Pest Management has set an important example by using models of insect infestation and damage that are intimately interrelated with the dominant forest growth and yield models. The PROGNOSIS extensions, MPB, Western Spruce Budworm, Douglas-Fir Tussock Moth, and the MPB contagion model under development indicate a potentially fruitful approach to be followed by other resource specialists.

CONCLUSION

The results of the model inventory and user survey have important implications for the further development of the Integrated Pest Impact Assessment System. First, there is a recognized need for systematic impact assessment models to support forest planning and management. Models that have a reasonably wide range of applicability, that provide for accurate projections across stand types and site types, and that are easy for users to access and implement will have a large and eager clientele. Achieving such a system of models presents a considerable challenge, but significant progress is already presented by such efforts as ECOSIM and the PROGNOSIS family of models. An adequate base of models which can be linked to provide pest impact predictions for a variety of resources already exists. However, it will still be necessary to develop impact prediction models for recreation, esthetics, and other socioeconomic concerns if forest management and planning efforts are to be aided in their attempts to meet the requirements of RPA, NEPA, and the Multiple Use and Sustained Yield Act.

REFERENCES CITED

Anonymous. 1983. Final report to USDA Forest Service, Forest Pest Management/Methods Application Group on a pest impact assessment system workshop. Milliken, CO, February 13-18, 1983.

Buhyoff, G.J., J.D. Wellman, and T.C. Daniel. 1982. Predicting scenic beauty for mountain pine beetle and western spruce budworm damaged forest vistas. Forest Science 28:827-838.

Buhyoff, G.J. and T.C. Daniel. 1984. Integrated pest impact assessment system: development and operations coordination. USDA Forest Service, Coop. Agreement 28-C4-320, FY84 Progress Report, September 1984.

Daniel, T.C., W.B. White, and D.O. Hunter. 1983. Integrated pest impact assessment system: an interface to a forest management information system. USDA Forest Service, Forest Pest Management/Methods Application Group, Fort Collins, CO, Rpt. No. 84-2, 22 pp.

Leuschner, W.A. 1979. Impact analysis, interpretation, and modeling. In Waters, W.E. (ed) Current Topics in forest entomology: selected papers from the XVth International Congress of Entomology. USDA Forest Service Gen. Tech. Rpt. WO-8, U.S. Government Printing Office, Washington, D.C., pp. 50-53.

Mason, G.N. 1984 (revised June). Southern pine beetle predictions handbook. USDA Forest Service, Integrated Pest Management RD&A Program, Southern Reg. Atlanta, GA.

Rykiel, E.J., M.C. Saunders, T.L. Wagner, D.K. Loh, R.H. Turnbow, L.C. Hu, P.E. Pully, and R.N. Coulson. 1984. Computer aided decision making and information accessing in pest management systems, with emphasis on the southern pine beetle. J. Econ. Entomology 77:1073-1082.

Schroeder, H.W. and T.C. Daniel. 1981. Progress in predicting the perceived scenic beauty of forest landscapes. Forest Science 27:71-80.

Thomas, J.W. (ed). 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service, Ag. Handbook No. 533, 512 pp.

APPENDIX A

First General Survey of Information on Prediction Models

SURVEY OF CURRENT

STAND AND IMPACT MODELS

Please return this survey to:

Gregory J. Buhyoff
Associate Professor
Forest Biometrics
Department of Forestry
Virginia Tech
Blacksburg, VA 24061

OR

Call: (703) 961-5148

We appreciate your assistance. If possible please return the survey or contact Greg Buhyoff by phone before May 11, 1984.

1. Please list the forest stand, pest or other impact models you are familiar with either as a user, or a developer. Please send along any publications or copies of documentation you may have for these models.

2. Are any of these models specific to Mountain Pine Beetle and/or Lodgepole pine? If so, which ones?

3. Do you know of any new models or modifications of existing ones which are currently under development? If so, give model name or type and if possible the name and address of an appropriate person to contact.

4. Of the models listed in No. 1 above which ones are most extensively used and in what Regions or Forests?

5. Are you aware of any reliability or validity testing on any of the models you listed in No. 1? If so, can you provide any documentation or the name and address of a contact?

6a. What types of predictions (i.e., types of impacts, etc.) do the models listed in No. 1 above give?

6b. Are there, in your opinion, other information needs that the models in No. 1 above should address or outputs that they should give?

7. What types of data bases or Geographic Information Systems do the models in No. 1 above interface with?

8. What type of maintenance or calibration procedures are followed for the models you listed in No. 1 above?

9. How would you rate (in a general sense) the success of the models you listed in No. 1 above for longer range forest planning or short range management alternative?

☆ U. S. GOVERNMENT PRINTING OFFICE: 1986—671-692/45,193 REGION NO. 8

Discussion Group C — Quantifying Impacts on Other Forest Resources

Modeling Social Impacts of Forest Management

T.C. Daniel
University of Arizona, Tucson, AZ 85721

A review of resource models and a companion user-needs survey (Buhyoff and Daniel 1984) was conducted within the USDA Forest Service. Survey results indicate that the use of computerized forest growth and yield models is intensive, widespread, and increasing. Comparatively, the availability and use of socio-economic models is far behind. Traditional economic analyses. relating management costs and discounted market returns, are frequently used. Sometimes more elaborate input-output analyses are used to assess more detailed effects on local, regional, or national economics. Explicit models of recreation, aesthetic, or wildlife impacts are hardly ever used. These forest resources typically enter the management decision-making system as after-the-fact, verbally stated recommendations, guidelines, general constraints or "rules of thumb" based on expert judgment. Represented in this form, it is not possible to determine the reliability or validity of assessments of these "other forest resources," nor can they be included with any precision, consistency or force in plan formulation, evaluation, or trade-off analyses.

One goal of the Integrated Pest Impact Assessment System (IPIAS) program is to promote the development of explicit models for assessing social impacts and to incorporate them as strong components of a comprehensive forest management information system. Recreation, tourism, and public perception of scenic beauty were included in the IPIAS development plan from the beginning (USDA Forest Service 1979). Specific models that were developed for the Front Range in Colorado achieved varying levels of success. It was demonstrated, however, that such models can be developed and integrated into a forest management information system. The basic requirements for forest social impact models are clear: quantitative measures of resource quantity and quality must be explicitly linked to measurable (manageable) biophysical characteristics of the forest. For example, a useful model for forest aesthetics must be able to predict changes in scenic beauty with reasonable precision (high, medium, or low is not adequate) given changes in forest variables that are typically available from inventory or stand growth and mortality projections (e.g., trees per acre in various size classes). Then the scenic consequences of alternative forest management actions can be assessed and compared with other benefits and costs.

Several models of forest scenic beauty have been developed and applied in the manner described above. Daniel and associates (Arthur 1977; Brown and Daniel 1984; Daniel et al. 1977, 1981; Schroeder and Daniel 1981) have developed models for predicting public perception of the scenic beauty of southwestern ponderosa pine forests, and Buhyoff and his colleagues (Buhyoff and Leuschner 1978; Buhyoff and Wellman 1980; Buhyoff et al. 1982) have developed models for the scenic beauty of forest vistas in the southeast. The ponderosa pine models relate judgments of public panels of scenic beauty to typical forest mensuration parameters (e.g., trees per acre in various size classes, volume of slash and downed wood, and measures of shrubs and ground cover).

The most recent models (Brown and Daniel 1984) are based on over 1,000 forest sites, each assessed for perceived scenic beauty and intensively inventoried. Multiple regression techniques were used to derive mathematical models relating standardized measures of perceived scenic beauty, the Scenic Beauty Estimate (SBE), (Daniel and Boster 1976) to forest inventory parameters. For example, one model for ponderosa pine stands was:

$$\text{Stand SBE} = 4.35 + 3{,}6079\ \text{PP24PL} + .2788\ \text{PDTOT} - 2.2606\ \text{DWV014}$$

Where:

PP24PL = Number per acre of ponderosa pine greater than 24 inches dbh.
PDTOT = Pounds per acre of herbage (grasses and forbs).
DWV014 = Cubic feet per acre of downed wood 0 to ¼.

This model achieved very good statistical quality (adjusted $R^2 = 0.76$, standard error of estimate = 12.02) and is intuitively reasonable; large trees and lush ground cover are positive scenic elements while downed wood has negative effects.

Applying the scenic beauty model in forest management and planning is straightforward. Standard forest inventories could provide the large pine, ground cover, and downed wood measures for forest stands of interest. Substituting these values into the equation above would yield a scenic beauty estimate for the stand. The effects of alternative management actions would be stimulated by an appropriate growth and mortality model (perhaps with a pest component) to provide projected new values (at various time steps) for the relevant forest feature. The projected values for these features would then be entered into the equation to yield expected scenic beauty values.

Using a similar approach, models have also been developed for recreation (e.g., Walsh and Olienyk 1981) and wildlife (Schamberger 1982). Social impact models of this type are only now being developed and they have not been extensively tested or applied. Thus, as with any model, it is always important to test the accuracy of predictions in each new situation, and, if

necessary, to calibrate for local conditions. Whether changes in specific social impacts are important in considering and selecting management alternatives will depend on several factors, including the "visibility" of the area and the nature of its use. In any case, having quantitative assessments and predictions based on explicit verifiable models can substantially enhance the forest manager's ability to include social impacts in formulating and evaluating management plans.

Literature Cited

USDA Forest Service. 1979. Meeting summary: planning and design workshop, Feb. 6-7, 1979, U.S. Dep. Agric., For. Serv., Rocky Mountain Region, Fort Collins, CO. 13 p.

Arthur, L.M. 1977. Predicting scenic beauty of forest environments: some empirical tests. Forest Science 23(2):151-159.

Brown, T.C.; Daniel, T.C. (1984). Modeling forest scenic beauty: concepts and applications. U.S. Dep. Agric., For. Serv., Rocky Mountain For. and Range Exp. Stn, Fort Collins, CO. Res. Pap. RM-256. 35 p.

Buhyoff, G.J.; Leuschner, W.A. 1978. Estimating psychological disutility from damaged forest stands. Forest Science 24(3):424-432.

Buhyoff, G.J.; Wellman, J.D. 1980. The specification of a non-linear psychophysical function for visual landscape dimensions. J. Leisure Research 12(3):257-272.

Buhyoff, G.J.; Wellman, J.D.; Daniel, T.C. 1982. Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas. Forest Science 28(4):827-838.

Buhyoff, G.J.; Daniel, T.C. 1984. Integrated pest impact assessment system: development and operations coordination. U.S. For. Serv., Coop. Agreement 28-C4-320, FY84 Progress Report, September 1984.

Daniel, T.C.; Boster, R.S. 1976. Measuring landscape esthetics: the scenic beauty method. U.S. Dep. Agric., For. Serv., Rocky Mountain For. and Range Exp. Stn., Fort Collins, CO. Res. Pap. RM-167. 66 p.

Daniel, T.C.; Anderson, L.M.; Schroeder, H.W.; Wheeler, L.W., III 1977. Mapping the scenic beauty of forest landscapes. Leisure Sciences 1:35-53.

Schamberger, M. 1982. Habitat: a rational approach to assessing impacts of land use changes on fish and wildlife. Pages 251-259 *in* The Environmental Professional, Vol 4, 1982.

Schroeder, H.W.; Daniel, T.C. 1981. Progress in predicting the perceived scenic beauty of forest landscapes. Forest Science 27(1):71-80.

Walsh, R.G.; Olienyk, J.P. 1981. Final report — recreation demand effects of mountain pine beetle damage to the quality of forest recreation resources in the Colorado Front Range. U.S. Dep. Agric., For. Serv., Rocky Mountain Region, Fort Collins, CO. 150 p.

Discussion Group C — Quantifying Impacts on Other Forest Resources

Forest Management Models: A Review and Users Need Assessment

G.J. Buhyoff

Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

T.C. Daniel

University of Arizona, Tucson, AZ 85721

The initial development of the Integrated Pest Impact Assessment System (IPIAS) focused on the ponderosa pine (*Pinus ponderosa* Laws) forests of the Front Range in Colorado. In particular, models were developed for predicting biological, economic, recreation, and aesthetic effects of a mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreak and of alternative insect-targeted management actions for that area. In the current stage of IPIAS research and development, the same basic integrated management information system structure is being applied to lodgepole pine (*Pinus contorta* Engelm.) forests in the Northwest. This test and extension of IPIAS will require several changes to the specific components of the original system; STAND, PEST, and social impact components developed for Front Range ponderosa pine forests cannot be directly applied to Northwest lodgepole pine forests. Thus, more appropriate model components must be found or developed.

To develop a solid basis for the extension of IPIAS, a comprehensive evaluation is being conducted of currently available models which might be candidates for application in the targeted northwest area (USDA-FS Regions One and Six). At the same time, a survey of model use and user satisfaction/needs at regional, forest and district levels has been initiated (Buhyoff and Daniel 1984). First, models have been identified and evaluative criteria developed, based on intensive personal interviews with individuals in Washington, D.C., in the Forest Research Stations, and in the Region One and Six staffs. Fifty-five individuals, all very familiar with the development and use of models for forest management and planning, were directly contacted in this phase of the evaluation and survey. As a result, 40 separate models or model extensions have been identified and evaluated and 29 models have been entered into a computer data base management system for quick reference and update. Documentation has been obtained for each model and where necessary, individuals who can clarify their use have been contacted.

The 29 models were deemed to have generalized applicability to Regions One or Six or to lodgepole pine, or to be potentially useful for assessing impacts as the result of mountain pine beetle infestations, or for making predictions regarding the behavior of such infestations. The 11 other models were comprehensively evaluated, but not included in the data base as their

Table 1
Models evaluated for IPIAS extension

A. ***Growth and Yield***	C. ***Economic Efficiency***
PROGNOSIS	*CHEAPO*
TRAS	*FORESTRY INVESTMENT ANALYSIS*
FREP/STEMS	*TRIM*
TWIGS	*DPDFSIM*
TRIM	*LP-DM-VOL*
ECOSIM	D. ***Harvest Scheduling***
GROW	*TREES*
DFSIM	*PROGNOSIS extension: EVENT MONITOR*
INDIDS	E. ***Wildlife***
TREES	*ECOSIM*
R2GROW	*PROGNOSIS extension: COVER*
RMYLD	F. ***Hydrology***
B. ***Insect/Pest***	*ECOSIM*
PROGNOSIS extensions:	G. ***Economic-Input/Output***
Western Spruce Budworm	*IMPLAN*
Douglas-Fir Tussock Moth	*MICRO I/O*
Dwarf Mistletoe	H. ***Debris***
Mountain Pine Beetle	*DEBMOD*
TREE LOSS FROM MOUNTAIN PINE BEETLE INFESTATIONS	I. ***Comprehensive Simulation***
INDIDS	*ECOSIM*
LP-DM-VOL	

applicability to IPIAS was considered minimal or nonexistent. In addition, 32 more trend prediction, management simulation, hazard rating, and growth models specific to southern pine beetle were evaluated and assessed as to their potential applicability to IPIAS. These models were not directly applicable to the development of IPIAS in Regions One and Six and were not included in the model data base, but several of the models and model concepts represented have served as useful guides for the IPIAS effort.

The 29 models now in the data base are categorized by prediction or analysis type and are presented in Table 1. Some models appear under more than one category because they perform more than one type of prediction or analyses.

Note that no range, recreation use, or visual quality models are listed. Although methods exist for developing such models, no specific models, either in use or under development, were identified by the survey. Although the wildlife category displays two models that can aid wildlife impact predictions, one is specifically incorporated in the ECOSIM model itself and the other (PROGNOSIS, COVER extension) makes projections of changes in shrubs and canopy that can potentially be used as input for wildlife population models. In fact, from our research, it seems that "rules of thumb" are more prevalent than are mathematical formulations for making predictions of changes in wildlife levels.

At this stage of the IPIAS program it is very difficult to further categorize the models which have been inventoried. Further evaluation of these models for the IPIAS system requires that the geographic area and time frame for the predictions be specified. The Integrated Pest Management Program for Southern Pine Beetle (Leuschner 1970 and 1984; Mason 1984) categorized models within a matrix defined by the interaction of time and area. This matrix (Figure 1) provides not only a means of categorizing models, but also a framework for making decisions about what an integrated impact system *should include*. IPIAS might include the entire matrix, some subset of contiguous cells or be restricted to a single cell, depending upon the needs and wishes of potential *users* of the system. One goal of the user needs survey is to help resolve such issues, and discussion of the geographic and time scale question will be a major agenda item for the IPIAS Steering Committee consisting of model users and developers.

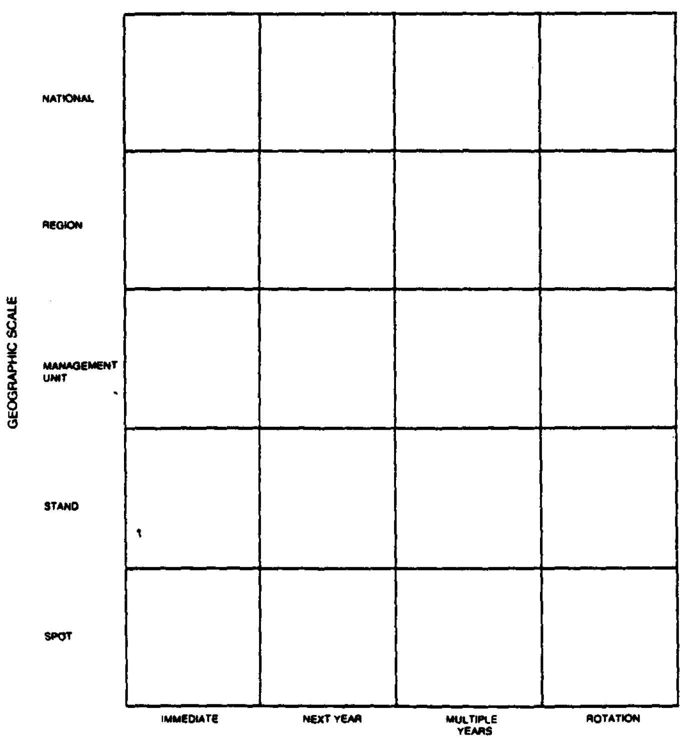


Figure 1. Time and geographic scale matrix incorporating model name and predictive information appropriate to integrated pest impact assessment systems.

Literature Cited

Buhyoff, G.J.; Daniel, T.C. 1984. Integrated pest impact assessment system: development and operations coordination. U.S. Dep. Agric., For. Serv., Coop. Agreement 28-C4-320, FY 84 Progress Report, Sept. 1984.

Leuschner, W.A. 1979. Impact analysis, interpretation, and modeling. Pages 50-53 *in* Waters, W.E., ed. Current topics in forest entomology; selected papers from the XVth International Congress of Entomology. U.S. Dep. Agric., For. Serv., U.S. Government Printing Office, Washington, D.C. Gen. Tech. Rep. WO-8.

Leuschner, W.A. 1984. Introduction to forest resource management. John Wiley and Sons: New York. 298 pp.

Mason, G.N. 1984 (Revised June). Southern pine beetle predictions handbook. U.S. Dep. Agric., For. Serv., Integrated Pest Management RD&A Program, Southern Region, Atlanta, GA.

Discussion Group C — Quantifying Impacts on ther Forest Resources

Integrating Social Impacts Assessment into Forest Management and Planning

W.B. White

USDA Forest Service, Forest Pest Management, Fort Collins, CO 80524

T.C. Daniel

University of Arizona, Tucson, AZ 85721

G.J. Buhyoff

Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

A discussion of techniques for assessing impacts of management on "other forest resources" is immediately hampered by the lack of clear definition of terms. "Other forest resources" does not specify the area of concern sufficiently to allow articulation of the relevant issues or development of a systematic approach to their resolution. Before proceeding, it is important to clearly define what is meant by "other forest resources." For our purposes, we will focus upon what are ...quently referred to as *Social Impacts*, as those ...pacts of forest management actions that affect the quality of the human environment. This approach is consistent with environmental legislation (e.g., NEPA, NFMA, and RPA) and would specifically include aesthetic, wildlife, recreation, and wilderness resources.

Current approaches to the assessment of social impacts tend to be more qualitative than quantitative and to rely on expert judgment rather than explicit analytical systems. As a result, it has been difficult to integrate these concerns with more traditional biological and economic factors in the formulation and evaluation of forest management options. Resource managers have recognized the need for more efficient and more effective methods for assessing social impacts, and for better integrating these impacts into the management and decision-making process.

A number of projects (e.g., Buhyoff and Daniel 1984; Rykiel et al. 1984; Turnbow et al. 1984; and Schomberger 1982) have been attempting to address this need. A 5-year research and development project (USDA Forest Service 1983) is currently underway to develop a computer-assisted forest management information system that links together: 1) biological (including forest growth and mortality, yield, and pest effects); 2) economic (stumpage values, management costs, and local and regional economic effects); and 3) social ...pact (recreation, scenic beauty, and wildlife) compo...nts. The Integrated Pest Impact Assessment System (IPIAS) (Daniel et al. 1983), as the name implies, consists of a linked set of models, data bases, and computer programs developed in the context of pest management concerns, specifically mountain pine beetle (*Dendroctonus ponderosae* Hopkins). IPIAS provides information assimilation and presentation rather than attempting to be an optimization or decision-making system. Because of its modular design and basis on vegetation-linked characteristics, IPIAS can be used to address a wide range of forest management problems.

Implementation of an IPIAS-type system within current forest management and planning procedures could take a form similar to that in Figure 1. The starting point is always an inventory of relevant forest resources. The inventory must be complete enough to operate the STAND model. In a typical IPIAS application, the timber staff and forest silviculturalist would run the STAND model, providing the needed parameters and formulating appropriate harvest, thinning, and pest management activities. Pest management specialists would provide up-to-date infestation or damage inventories and other parameters (e.g., attack ratios for insects) needed to integrate the PEST model with the STAND model. Output from the STAND model would drive a set of resource models, each operated and interpreted by the appropriate planning or management specialist. For each modeled management alternative, resource specialists would provide their evaluation and recommendations, supported by the related model projections of location, timing, and magnitude of predicted effects. Mathematical stand growth and economic models are already routinely used and of great value to timber specialists and economists. Recreation, wildlife, and scenic value models are not generally available at this time, but there are some promising efforts underway. When developed and integrated into a comprehensive information system, such models can enhance the precision, reliability, and usefulness of social impact variables in the forest planning and decision-making process.

The 5-year research and development project (USDA Forest Service 1983) charts a course of action to strengthen the current version of IPIAS. Some of the major areas of development are: 1) survey and evaluate user needs; 2) identify appropriate linkage needs between various resource models: wildlife, fire, scenic beauty, recreation, etc.; 3) develop specifications and model contagion phenomenon (risk rating or hazard

rating) relative to mountain pine beetle effects in a large contiguous forest type, e.g., lodgepole pine (*Pinus contorta* Engelm.) within a major drainage.

IPIAS is not intended to make decisions for the resource manager; however, it can give him a multidimensional display of the various trade-off interactions expressed in either relative values (e.g., scenic beauty quotients and recreation use days) or various economic parameters (stumpage value, tourist expenditures). The key point for the resource manager to be aware of is that all these impacts cannot be displayed as a simple total or are they necessarily all negative impacts. We can give the manager the information to help him make a decision. We cannot tell him how to weigh the various trade-offs in making his final decision.

Literature Cited

U.S. Fish and Wildlife Service 1983. Final report to USDA Forest Service, Forest Pest Management/ Methods Application Group on a Pest Impact Assessment System Workshop. Milliken, CO, February 13-18, 1983.

Buhyoff, G.J.; Daniel, T.C. 1984. Integrated pest impact assessment system: development and operations coordination. U.S. Dep. Agric., For. Serv., Coop. Agreement 28-C4-320, FY84 Progress Report, September 1984.

Daniel, T.C.; White, W.B.; Hunter, D.O. 1983. Integrated pest impact assessment system: an interface to a forest management information system. U.S. Dep. Agric., For. Serv., Forest Pest Management Methods Application Group, Fort Collins, CO. Rep. No. 84-2, 22 p.

Rykiel, E.J.; Saunders, M.C.; Wagner, T.L.; Loh, D.K.; Turnbow, R.H.; Hu, L.C.; Pulley, P.E.; Coulson, R.N. 1984. Computer-aided decision-making and information accessing in pest management systems, with emphasis on the southern pine beetle (Coleoptera: Scolytidae). Texas A&M University, College Station, TX. 34 p.

Schamberger, M. 1982. Habitat: a rational approach to assessing impacts of land use changes on fish and wildlife. Pages 251-259 *in* The Environmental Professional, Vol. 4, 1982.

Turnbow, R.H. Jr.; Hu, L.C.; Rykiel, E.J.; Coulson, R.N.; Loh, D. 1983. Procedural guide for FERRET, the question analysis routine of the decision support system for southern pine beetle management. Texas Agricultural Experiment Station, College Station, TX. 21 p.

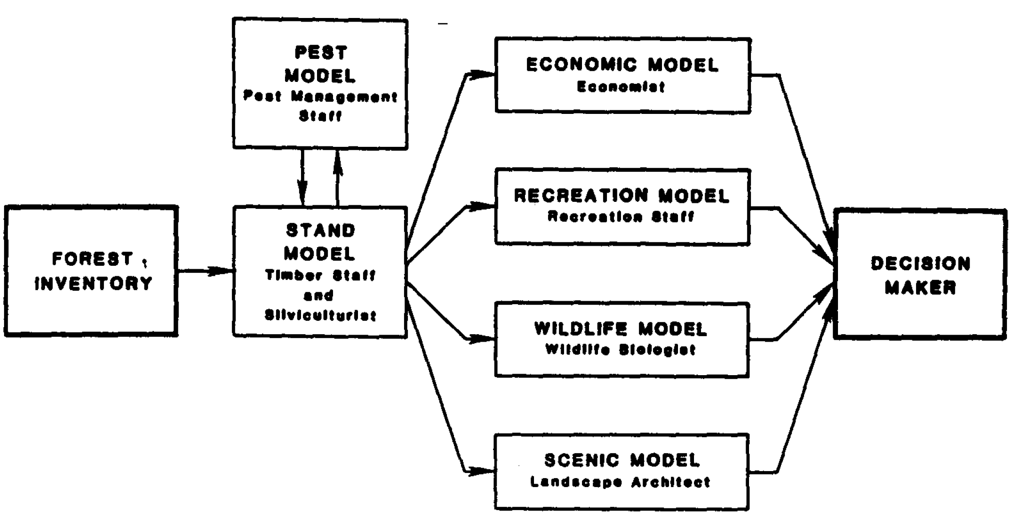


Figure 1. Schematic outline of IPIAS as implemented within a general forest planning framework.

Discussion Group C — Quantifying Impacts on Other Forest Resources

Summary

W.B. White

USDA Forest Service, Forest Pest Management, Fort Collins, CO 80524

There are several indications, including the proceedings of this symposium, that quantitative computer-implemented models will play an increasingly important role in all aspects of forest planning and management.

Development and integration of these models, and merging them with the other elements of forest management systems will be a major task for research and management. In that context, considerable progress has been made in the measurement and modeling of recreation, wildlife, and aesthetic benefits. The next phase will be to integrate the assessments of impacts on these forest resources into a pest management system.

From information presented at this symposium, it is evident the CANUSA Spruce Budworm Program has made excellent progress in developing some of the major components of a comprehensive impact assessment system. Important biological, silvicultural, and economic relationships have been documented with considerable precision. Although the social impact assessment procedures reviewed were developed in a different context (mountain pine beetle/lodgepole pine), they could be extended and combined with the major budworm biological components to produce a comprehensive management information system. By attention to the linkages among component models, and adding the essential geographic information elements, a valuable operational system could be near at hand.

Forest environments are immensely complex and knowledge of how the forest system works and how it is affected by insects and diseases and management actions is continually improving. A 5-year program of research is underway to develop an Integrated Pest Impact Assessment System (IPIAS) for mountain pine beetle in the northwest. Biological, silvicultural, economics, and social impact models are being pulled together to address the management information needs identified by resource managers on the demonstration forest, the Nezperce. This exercise will, no doubt, be a learning experience because there is no point at which a system becomes final.

Development of IPIAS will continue, supported by advice on how the overall concept can be kept flexible enough to accommodate other pest applications in the future.

LINKING COMPUTER GENERATED FOREST VISUAL SIMULATIONS TO GEOGRAPHIC INFORMATION SYSTEMS[1]

Robert M. Itami[2]
Terry C. Daniel[3]

Abstract: Perspective simulations showing visual effects of forest management alternatives are an essential tool for forest landscape architects. Programs such as PREVIEW and Perspective Plot use computer graphics to simulate before and after views of forest management alternatives. The problem with these programs is that they require a separate data entry system which is redundant to GIS data bases that may already exist. This is a waste of time and money and a possible source of errors. This paper describes a program which links the gridded elevation and timber stand files of the MOSS GIS system to the perspective graphics program PREVIEW.

INTRODUCTION

Visual Simulation in Forest Environments

Visual Landscape Simulation refers to a set of techniques for representing existing landscapes or proposed changes in landscapes through a variety of visual media, including hand rendered sketches, 3-dimensional scale models, computer generated plan and perspective graphics, photo-montages, video digitizing and computerized "painting" programs, and image processing. Visual Simulations may employ a combination of these techniques and vary in the degree of accuracy and representativeness. The purposes of visual simulations are to assist planners, decision makers, and the public in appraising the impacts of human-induced or natural landscape changes. As such, visual simulations play an important role in the process of visual management systems (VMS) such as those employed by the the USDA Forest Service.

The USDA Forest Service has contributed consistently over the last decade to the field of computer generated visual simulations. Computer programs for generating perspectives such as Perspective Plot (Twito and Warner, no date), SCOPE (Warner and Nickerson, 1977), and PREVIEW (Myklestad and Wager, 1976) use the digitized elevation and vegetation data interpolated to a grid matrix. These 'special purpose' programs are employed primarily to assist forest landscape architects in their visual impact assessment work. The programs all serve the function of producing 3-dimensional views of the landscape by calculating the perspective transformation of the gridded elevation to produce a 'distorted grid' or 'fishnet' perspective view of the landscape. The advantage of the approach is great flexibility, since the landscape architect need only specify the viewer position and the center and angle of view to quickly produce perspective views from different locations in the landscape. In addition, programs such as Perspective Plot and Preview also have the capability of producing simulations of impacts from different timber harvesting practices. By using assumptions about tree growth over time, landscape architects can simulate the changing visual impacts over time by having the computer program 'grow' the trees over the specified time and showing the change in perspective (figure 1).

Problems with single purpose digital data bases

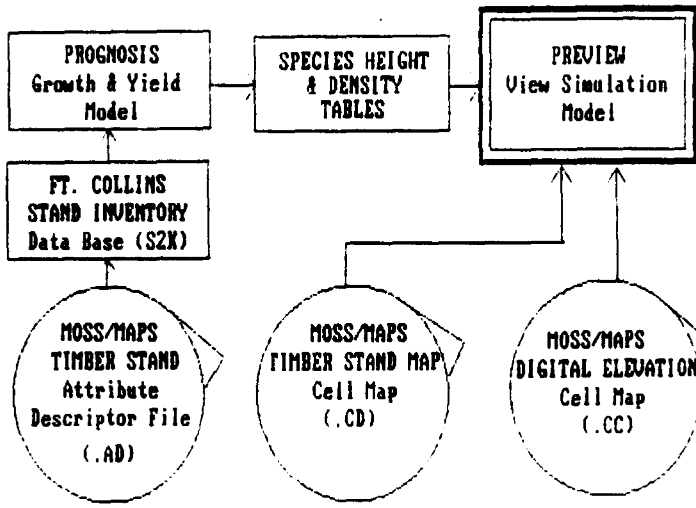
The advantages of computer generated perspectives are clear, the disadvantages revolve around data entry and management problems. Presently, the landscape architect

---

[1] Paper presented at the conference on Spatial Data Systems for Management. (University of Arizona, November 5-6, 1987)

[2] Robert M. Itami is an assistant professor of Landscape Architecture at the University of Arizona, Tucson, Arizona.
[3] Terry C. Daniel is professor of Psychology at the University of Arizona, Tucson, Arizona

GIS Forest Visual Simulation Modeling Framework



or digitizing technician must digitize and grid the elevation for the study area. The data is in the format of the specific program in use (eg. Perspective Plot data formats are different that Preview formats, though they are functionally similar). If another professional wishes to generate a slope map or a cut and fill map on the computer, she may have to redigitize the same data into the file formats unique to the application. Clearly as more and more computer applications emerge, the redundant digitizing of the same data set is inefficient and expensive. An integrated data base structure for land information is therefore desirable. It is in this context that geographic information systems become a critical link in a wide range of applications.

GEOGRAPHIC INFORMATION SYSTEMS AS AN INTEGRATED FRAMEWORK FOR FOREST APPLICATIONS

Geographic information systems have the advantage of providing a consistent coherent data structure for mapped data. In addition GIS provides a powerful set of operators that are common to a wide range of applications. As GIS systems are implemented in a growing number of forest districts, it is clear that the tools of the forest landscape architect must be integrated in this environment. Once an elevation map is digitized into the GIS database framework, the same map may be used to generate slope, aspect, and viewshed maps. In addition the computer can generate distance zones required by the forest service visual management system. With these operators available to the landscape architect, it is clear that significant advantages can be gained by integrating visual simulation technologies into this environment. The rest of this paper discusses the approach used in the Integrated Pest Impact Assessment System (IPIAS).

THE VISUAL IMPACT ASSESSMENT MODULE OF THE INTEGRATED PEST IMPACT ASSESSMENT SYSTEM (IPIAS)

The Integrated Pest Impact System (IPIAS) evolved in response to the need to model impacts from the devastating effects of mountain pine beetle in forest of the Rocky Mountains. The Visual Impact Assessment Module (VIAM) is one component of the larger IPIAS framework which includes models for forest productivity, stream sedimentation, fisheries, wildlife habitat, and mountain pine beetle infestation contagion models. IPIAS utilizes the MOSS/MAPS (USDI US Fish and Wildlife Service, 1984) spatial data base and GIS operators to host the models.

The IPIAS database is comprised of a set of map themes including timber types, transportation network, large game summer and winter ranges, recreation sites, streams and other waterbodies, administrtive boundaries, elevation data, and other map variables which the various IPIAS models share in the modeling process.

The VIAM follows the framework of the existing Visual Management System used by the Forest Service. Visual simulation has been designed as an integral component of the IPIAS visual impact assessment module. The following section describes the specifics of the IPIAS implementation of PREVIEW.

IPIAS PREVIEW VISUAL SIMULATION

The IPIAS visual simulation program stems from the original PREVIEW (Myklestad and Wager,1976) program. IPIAS runs on Data General MV series mini-computers. The source code is in Fortran 77 and data files used by IPIAS (viz. MOSS/MAPS) are all in Fortran binary formats. These systems constraints eliminated modification of the more recent Perspective Plot (Warner and Nickerson, 1977) software which is written in Hewlett Packard Basic for an HP-9000 series super microcomputer. The source code was obtained from BLM Supervisor's office in Portland, where Todd Stille had modified the original Fortran source code to Data General Fortran V. Stille had made major modifications in terms of data structure and wrote a digitizing front end for the program. Stille's excellent documentation made the translation to Fortran 77 and the links to the MOSS/MAPS data files efficient.

The integration of the PREVIEW software into the IPIAS VIAM framework involves two distinct but inter-related processes. First PREVIEW must receive its data from MOSS/MAPS data files. This includes both the digital elevation model which is the gridded elevation map data (continuous cell data), and the timber stand data (discrete cell data). Second IPIAS PREVIEW then must take the stand attribute descriptors for each stand in the map data base and look up the mix of species height and density for each stand. This look up table is generated by the PROGNOSIS growth and yield model which has been enhanced to include Mountain Pine Beetle infestation models. The geographic location of each stand is referenced on a cell by cell basis in the MOSS cell map which contain a numeric value which points to the alphanumeric label in MOSS/MAPS attribute descriptor file. The alphanumeric label in this file is the same reference label used in the PROGNOSIS generated lookup table of species height, and density for each stand.

PREVIEW first reads the MOSS DEM cell file. Next the user selects the viewer position, the center of view, the horizontal angle of view and the extent of the cell data base to view. For preliminary analyses, the user may also select different sampling densities to compose the view before executing the final plot. A 100 percent sample will plot every cell in the designated view area. A 50% sample will plot every other column and every other row in the designated view area. This speeds up execution of the program and substationally reduces the time required to plot the perspective.

PREVIEW need generate the perspective transformation only once per view since the growth simulation for each view is independent of the perspective transformation component of the model. In the Timber stand simulation, IPIAS PREVIEW reads the rasterized timber map and plot the correct tree symbol by cross referencing the attribute descriptor of the cell to the species height and density lookup table described earlier. This allows an unlimited number of stands with varying species mixes, heights and densities. In earlier versions of PREVIEW the landscape architect was limited in the total number of timber stands that could be simulated. To simulate before and after views. PROGNOSIS generates a lookup table for each year of the simulation. The landscape architect need only select the year of the simulation and the corresponding PROGNOSIS lookup table will be used to generate the simulation.

As a result digital map data has a distinct advantage over paper maps in terms of the flexibility of analysis and display. The accuracy of the perspectives generated by these programs are related to the accuracy of the digitized data. Computer graphics generated by this technique lack realism because of the abstract representation of the ground plane as a distorted grid, overly simplistic graphic representation of vegetation, and lack of ground texture, understory vegetation, and effects of light and shadow. However these perspectives are useful to the professional wishing to visualize the magnitude and character of visual impacts.

The Future

Now that the data integration has been accomplished, advanced computer graphics, including image processing and raster graphics techniques can be used to generate simulations with photographic realism. By combining the video imaging technology and computer paint programs with the quantitative approach used in PREVIEW simulations, the landscape architect will be able to quickly and accurately produce realistic visual simulations that approach the quality of television.

REFERENCES

Bishop, I.D., R.B.Hull, P.N.A. Leahy. 1985. Visual Simulation and assessment of electricty transmission towers. Landscape Australia 7:3, 190-199.

Myklestad, Eric and J.Wager. 1976. "PREVIEW: Computer Assistance for Visual Management of Forested Landscapes," Research Paper NE-355, 1976, USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA.

Sheppard, Stephen R.J. 1985 "Illustrating Future Landscapes: A User's Guide to Visual Simulation" unpublished manuscript.

Travis, M.R., G.H. Elsner, W.D. Iverson, and C. Johnson. 1975. "VIEWIT: Computation of seen areas, slope, and aspect for land-use planning." Technical Report PSW-11/1975, USDA Forest Service, Berkeley, CA.

Twito, Roger and J.Warner. no date. "Perspective Plot Program for Evaluating Visual Impact of Proposed Timber Harvest Units with Desktop Calculator, Plotter and Digitizer" USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

USDI Bureau of Land Management. 1980. Visual Simulation Techniques. BLM Division of Recreation and Cultural Resources, Washington, D.C.

USDA Forest Service. 1974. "The Visual Management System" National Forest Landscape Management, 2. Agriculture Handbook Number 462, Washington D.C.

Warner, John and D. Nickerson. 1977. "SCOPE" Logging Systems Group, USDA, Forest Service, Oregon State University, Corvallis, OR.

In Press: Artificial Intelligence Applications in Natural Resources.

INTEGRATED COMPUTER DECISION-SUPPORT FOR FOREST IMPACT ASSESSMENT: A CONCEPTUAL FRAMEWORK AND EXAMPLE

by

G. J. Buhyoff, W. B. White, T. C. Daniel, and D. O. Hunter

Introduction

Information management and analysis is one of the biggest problems facing forestry and related natural resources management. Good decision-making by natural resource managers and planners depends upon efficient information gathering, organization, and analysis. The requirements for data gathering, manipulation and collation have increased as a function of three main factors: (1) increased requirements, legislative and otherwise, to assess the interrelationships and production capabilities of multiple resource bases; (2) increased capability and accessibility of computer and other automated data processing technologies; and, (3) increased numbers and sophistication of mathematical prediction systems.

Although the demands from resource managers and planners for more elaborate information retrieval and processing have increased, information analysis and delivery systems have not kept pace with these demands (Daniel, et al. 1983). Thus, in a sense, our data input and analysis requirements are greater in quantity and complexity than our output generation systems are capable of handling, given their current lack of sophistication and integration.

Computer hardware is no longer the limiting factor for problem solution development--software is. Hardware technology has developed faster than software technology. The implementation of integrated and cohesive software solutions to resource management problems lags far behind the development of modeling and data management technologies.

THE AUTHORS: Gregory J. Buhyoff is Professor and Director, Center for Quantitative Studies, School of Forestry and Wildlife Resources, Virginia Tech, Blacksburg, VA. William B. White is an Entomologist with the USDA Forest Service, Fort Collins, CO. Terry C. Daniel is Professor of Psychology and Renewable Natural Resources, University of Arizona, Tucson, AZ. Don O. Hunter is an Ecologist with the USDI, Fish and Wildlife Service, Fort Collins, CO.

Other problems related to information analysis in forestry and related renewable natural resource contexts revolve around the non-use of quantitative prediction models and related tools. Mathematical models are often not used because they "appear" to be too complex, have not been thoroughly developed or adequately tested in wide ranging field applications, are not compatible with existing input data, are not integrated with analysis systems currently utilized, do not provide output in the required format or are not readily available for use because of elaborate computational hardware requirements (Buhyoff, et al. 1986). Specifically, singular, formal, mathematical models are sometimes not well suited to solving the common unstructured problems encountered by natural resource managers and planners. That is, foreseeing the kinds of problems that will arise or when they will develop is not always possible. Therefore, problem solving is done in an ad-hoc, unstructured way. Information management and analysis systems of the future must permit users to create novel problem solving structures and to analyze and organize models and data in ways that are meaningful. Most often resource managers do not know what information and models can be linked, or, for that matter, how to do it. This unstructured decision-making process can be frustrating, at best, or can lead to erroneous decisions because of the misuse of models.

Finally, much of the information which can be brought to bear in solving natural resource management problems is often not readily available or is in a form which cannot be widely used. Much of the information related to specific problem analyses is in the form of elaborate decision-rule-bases which can only be garnered from the experience of experts who are familiar with a particular problem or gleaned from the "facts" resulting from years of research and other empirical observations. Decision-rules about certain problem solutions can become complex to the point of not being understandable by any particular person, or not being useable in problem solutions without computerized analysis systems.

This paper discusses what we feel is a framework for better and faster forest management decision-making. Also, an example implementation of this system framework is outlined.

A Forest Management Decision Support System Framework

It is logical to assume that as greater computer hardware capacities come on-line and become available at the management unit level, there will be a demand for greater information analysis sophistication. It is also probable that many more management decisions will become more decentralized as the capacity for problem analyses increases at, for example, the management unit level. It is suggested here that it is not too futuristic to be examining and building the linkages between Geographic information systems (GIS), Tabular resource data bases, prediction models, and simulations and artificial intelligence concepts.

It seems plausible that integrated computer-based technologies can be used to design decision support systems (DSS) with user transparent linkages between these technologies. Under our concept, a GIS and other tabular resource data bases would serve as input files for a "driver" simulator or model (e.g., a forest growth simulator). This driver then creates the input data matrices for a series of linked impact or resource response models (e.g., fisheries habitat, stream sedimentation, pest outbreak, economic impact, etc.). The information resulting from execution of the response models would then be output as tables, maps, or other graphics. This type of system would allow users to ask "what if" questions and could also be structured to analyze many different management scenarios. It seems possible to further extend the idea by having expert systems serve as "operating shells" around portions of this larger system (e.g., expert systems for model selection, problem determination, model interpretation, pest outbreak and contagion, etc.) or in lieu of formal mathematical models where the response criterion is qualitative.

GIS's will likely be central components of such comprehensive decision support systems. Specifically, GIS's can provide (1) the vehicle for the development of common data bases without data redundancy across applications or uses; (2) a data base which can be updated easily; (3) the ability to analyze and manipulate data within the "real-world" structure of complex resource relationships; and, (4) different users can be provided with different "views" of the data. This last item is particularly important since the data generation and reporting requirements of different resource management

functions (e.g., wildlife, timber, fisheries, recreation, et.) are often quite different and have, therefore, led to the creation of many incompatible data bases.

A typical computerized GIS data base contains a number of different types or "themes" of data, usually pertaining to the same geographic area. Map or cartographic data, such as public land survey lines, topographic features, or other map-related features with locational or spatial attributes are the types of data most commonly included in a natural resource data base. The data base may also contain other types of data such as locations of pest outbreaks, important big game ranges, recreation sites, or economically valuable timber stands. These data themes can be organized by polygons rather than, say, pre-specified plot shapes. The computerized GIS performs many of the types of spatial manipulations traditionally performed manually, except that it is faster and more efficient (Goulet, et al. 1981, Tomlin, et al. 1981). In addition, the GIS can be used for the logical or arithmetic compositing of many maps at one time, a task that cannot easily be done manually. Resource changes through time can be stored continually and displayed dynamically from a GIS. In fact, many queries of a natural resource management DSS may be addressed by "simple" output from GIS's alone an may not require predictions from other formal prediction/response models.

More specifically, GIS type data bases integrated with other tabular (e.g., forest mensuration) data bases appear to be the type of data structure which could serve as a vehicle for linking together many types of prediction models and/or simulations into more comprehensive DSS's (Sprague, 1980). These types of systems would be especially useful for providing evaluative information for structured and unstructured resource management problem solving as well as for testing decision rules.

Linkages between GIS and artificial intelligence should also be possible within this framework. For example, an expert system could be used to "call" or "load" a GIS for the purpose of supporting "what-if" questions for the purpose of optimization of a particular decision and the determination of what should be done with regard to the expert-estimated parameter. An example of this might be the optimal location of logging roads. Further, expert systems may be able to act as GIS use "tutors" and "suggest" ways GIS's can be used to answer resource management questions.

Truly integrated resource management will likely require such comprehensive information analysis or decision support systems. The development of such systems and the establishment of guidelines for their construction could be one of the most important research and development tasks which lie ahead.

A Pest Management Example

Each year approximately 2.4 billion cubic feet of timber are lost in the United States as a result of forest insects and disease. Dead trees may diminish habitat for some wildlife species, while simultaneously improving the habitat for others. To a homeowner in an affected area, the loss of trees may have devastating effects on property value. Elsewhere, landowners may view dead trees as an abundant source of inexpensive fuel. Therefore, there are many complications resulting from forest pests. Historical assessments of pest-caused timber loss have been relatively uncomplicated with each impact being predicted as a singular, unconnected resource response. Assessing pest-caused impacts which include intertwined biological, social, or economic effects will require more complex assessment methods. In an effort to improve the efficiency and effectiveness of impact assessments and to support pest management recommendations, the USDA Forest Service, Forest Pest Management/Methods Application Group initiated a five-year program in 1984 to develop the Integrated Pest Impact Assessment System (IPIAS). The objective was to be the improvement of assessments for biological, economic, and social impacts of alternative forest and pest management actions. Further, this software was to do a better job of integrating this impact information into the overall forest management and decision-making process.

After completing a comprehensive survey of Forest Service user needs for impact predictions from forest pests (Buhyoff, et al., 1986), a year was spent defining the specifications, data standards, and requirements for IPIAS (recently renamed INFORMS--Integrated Forest Resource Management System). It was determined that IPIAS should be a computer-assisted forest management decision support system which would link forest inventory, geographic information, forest growth and mortality models, and resource response or impact models for assessment of forest pest impacts. IPIAS

(Figure 1) has three basic components: (1) a data base management system that integrates tabular (multiattribute) geographic (map) and user-supplied data; (2) a set of forest models for projecting growth and mortality effects of management actions, insect or disease damage, or other biological changes; (3) a set of impact models for predicting the environmental, social, and economic consequences of projected changes in forest conditions.

General System Operation

First, the user geographically defines a study area. This is accomplished by either selecting collections of stands already in the Geographic Information System (GIS) data base or by directly delineating a new study area on a graphics terminal. Depending upon the potential impacts that the user wishes to predict and investigate, different combinations of forest growth and pest damage models contained in a model library are called by the system. Input data for these prediction models are software determined and are automatically supplied from one of the resident tabular data bases (e.g., stems per acre), or from the geographic information system (e.g., acres of pest-damaged trees). The system determines what other information is required but not supplied by a resident data base. For example, it may ask for information about future logging road segments. This information is input by the user at a terminal. Biological models then predict future forest conditions such as the number of pest-killed trees, at specific time intervals resulting from the simulated management option. These projected forest conditions are output so that they may be reviewed by appropriate management specialists before being used by the resource impact/response models. The response models predict change in such things as wildlife habitat suitability, scenic quality, or economic outputs (e.g., present net value) resulting from the predicted changes in forest conditions. Summaries of all these effects are displayed as tables, graphs, or maps for the study area. The basic IPIAS framework remains essentially the same from one application area the another. Therefore, the framework is generic, the specific application is custom-tailored. The specific data bases and prediction model modules used by the system will differ; however, each time the system is used different data and models will be "called" and interfaced by the software for answering different resource impact questions.

System Implementation

A precursor to IPIAS developed during the period 1981-1983, for example, focused upon the recreation and aesthetic impacts of mountain pine beetle damage to ponderosa pine forests on the Pike-San Isabel National Forest in Colorado (Daniel, et al. 1983). This early system was implemented on stand-alone microcomputers which proved to be too small and slow for such a comprehensive system. As a result, later implementations focused on larger systems of at least several mega-bytes in memory size and with higher speed processors. The most current version is currently being employed by resource specialists on the Nezperce National Forest in Idaho and executes on a Data General MV series computer. The Nezperce system was designed to analyze impacts resulting from a mountain pine beetle infestation in the Red River drainage. There, forest managers are concerned that increasing tree mortality will have major impacts upon a multitude of resources other than timber. For mortality will have major impacts upon a multitude of resources other than timber. For example, in the Red River area anadromous fish are very sensitive to disturbance in the watershed. The Nezperce IPIAS implementation can provide information about fisheries impacts by analyzing the effects of alternative harvest strategies upon sediment and fisheries in a proposed sale area. The various harvest strategies can then be designed to deal with the mountain pine beetle outbreak in the lodgepole pine forests. Further, the resident GIS manipulates and stores spatial data themes relevant to forestry practices in the Red River drainage (i.e., timber stands, roads, logging practices, fire history, and prescription watershed boundaries). Data from the GIS also input to models developed to simulate sediment production and the resultant sediment loading on salmonid production. Tables 1 and 2 example system model outputs for one unique harvest prescription on one watershed in the Red River drainage. Map products visually displaying the affected areas augment these tabular outputs (Figure 2). Other resource response components of IPIAS include elk habitat, general wildlife cover, timber economics, visual sensitivity, and insect contagion analyses. All of these analyses use

"off-the-shelf" models which have been included in the system model library. Managers on the Nezperce National Forest estimated manpower savings of 75 percent using the initial version of IPIAS in preparing environmental analysis reports (personal communication, Nezperce personnel).

Conclusion

The Nezperce implementation of our proposed DSS framework indicates that the concept seems viable. More complicated problems can be addressed and time efficiencies realized with integrated computer technologies. However, much additional work is required to both expand and "hone" such systems. Interfacing existing resource impact models is not an easy task as few are suited "as is" to the computerized data structures which are used in such a system. Some models will need to be restructured or rebuilt to fit system file standards (e.g., GIS file structure, etc.). Calibration and validation of these models will also be required. Additionally, cascaded error problems in the linkages between input data type and prediction models and between the models themselves will need to be investigated. Finally, artificial intelligence concepts need to be implemented. Current efforts are directed at adding to the set of models available for integration into the system and at improving the user interface to make it more powerful and easier to use. Improvements to the biological model components, especially adding the capability to predict the spatial/geographic spread of mountain pine beetle damage in lodgepole pine (Hamilton, et al. 1985), are also the focus of substantial research and development effort. Despite the scale of the job ahead we feel that a system like IPIAS is a logical tool for the decision support needs of natural resources managers.

Literature Cited

Buhyoff, G. J. and T. C. Daniel, W. B. White, and D. O. Hunter. 1986. Integrated Pest Impact System Development: Impact Model Inventory and Use Survey. Report No. 86-5, USDA, Forest Service, Forest Pest Management, MAG, Fort Collins, CO. 14 pp.

Daniel, T. C., W. B. White, and D. O. Hunter. 1983. Integrated pest impact assessment system: an interface to a forest management information system. USFS, Forest Pest Management, Methods Applications Group, Report No. 84-2. Fort Collins, CO. 20 pp.

Goulet, J. R., Jr., J. K. Sailor, J. K. Berry, and K. Sherman. 1981. Computer-assisted map analysis of marine ecosystems information. p. 269-272 in oceans 81, Conference Record Vol. One. Sept. 16-18. Boston, MA.

Hamilton, D. B., J. E. Roell, and W. B. White. 1985. Mountain Pine Beetle Damage and Contagion Modeling: Some Concepts and Approaches. USDA Forest Service, FPM/MAG, Fort Collins, CO. Rpt. 85-6.

Sprague, R. H. 1980. A framework for the development of decision support systems. MIS Quarterly. 4:1-26.

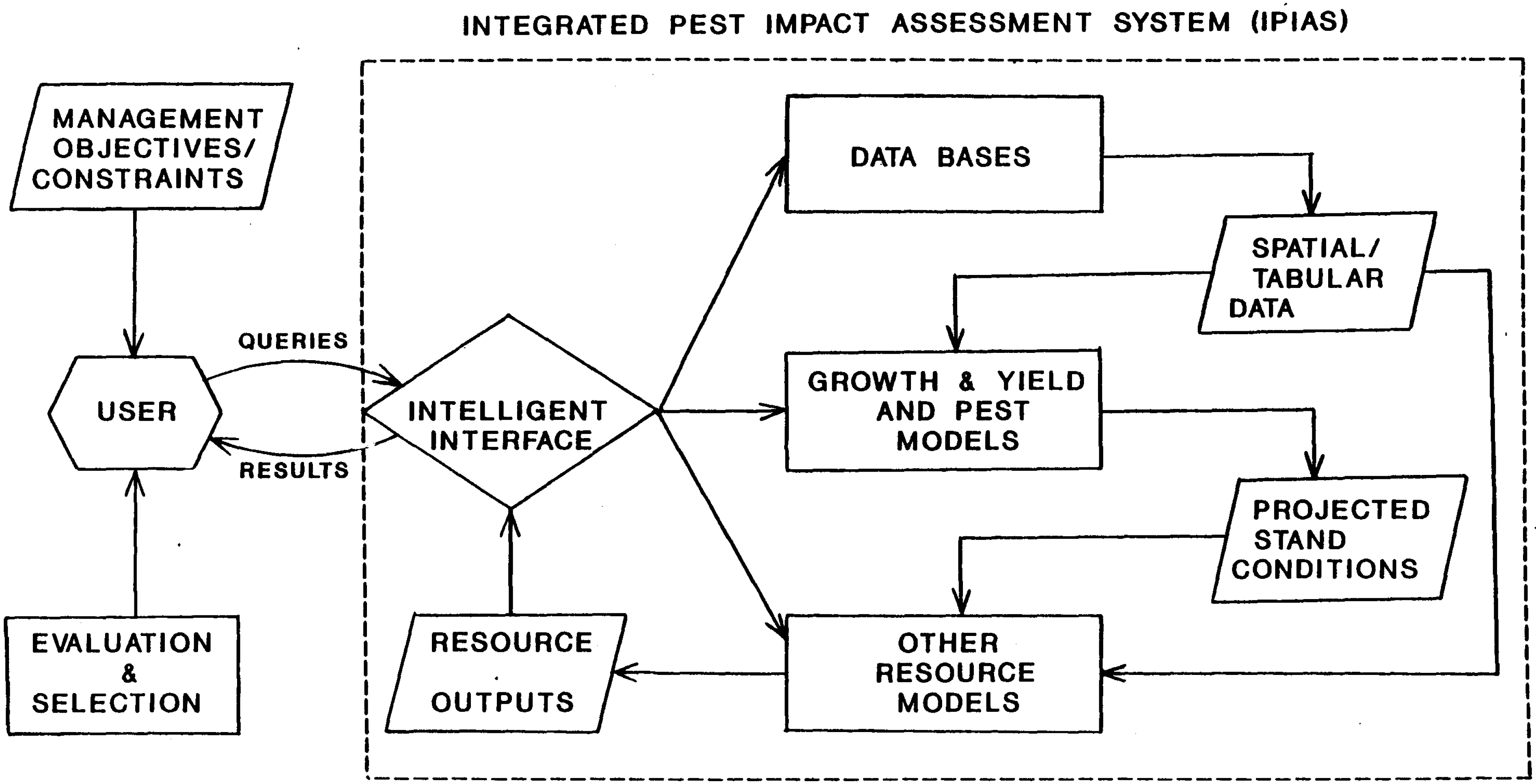
Tomlin, D. C., J. K. Berry, and S. M. Tomlin. 1981. Fundamental overlay mapping techniques. P. 470-481 in In-place resource inventories: principles and practices. Proceedings of a national workshop, Soc. of American Foresters. Aug. 9-14, University of Maine, Orono, ME.

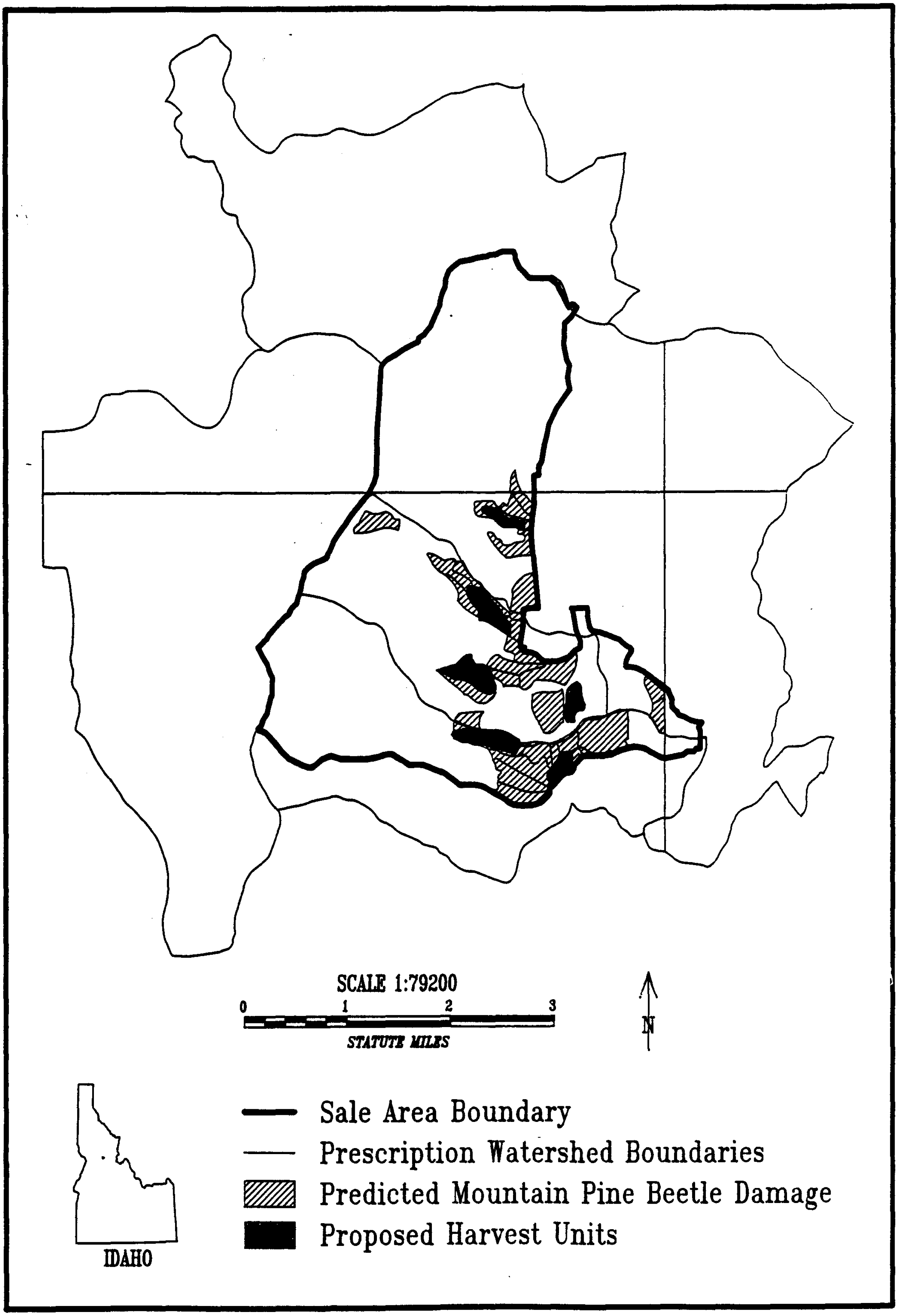
Table 1. **Sample yearly summary of sediment yield for a unique prescription in one watershed in the Red River drainage.**

Year	Natural Sed. Yield (T/MI2/YR)	Management Induced Sed. (T/MI2/YR) Roads	Logging	Fire	Total Sed. Yield (T/MI2/YR)	Increase Over Natural (Percent)
1985	12.23	4.76	.00	.00	16.99	38.96
1986	12.23	4.67	.09	.00	16.99	39.94
1987	12.23	4.65	.16	.00	17.03	39.32
1988	12.23	4.65	.10	.00	16.97	38.80
1989	12.23	4.65.	.07	.00	16.94	38.59
1990	12.23	4.65	.04	.00	16.92	38.35

Table 2. Sample yearly summary of fisheries impacts for a unique prescription in one watershed in the Red River drainage.

Year	Substrate Embeddedness	Fines by Depth	Embryo Survival (Percent)	Sum. Rearing Capacity	Win. Carrying Capacity
Natural	20.08	.00	.00	97.50	50.52
1985	23.59	.00	.00	96.48	44.85
1986	27.09	.00	.00	95.30	39.81
1987	30.63	.00	.00	93.92	35.30
1988	34.12	.00	.00	92.40	31.34
1989	37.60	.00	.00	90.71	27.85
1990	41.05	.00	.00	88.86	24.77


INTEGRATED PEST IMPACT ASSESSMENT SYSTEM (IPIAS)
MANAGEMENT OBJECTIVES/ CONSTRAINTS
USER
QUERIES
RESULTS
EVALUATION & SELECTION
INTELLIGENT INTERFACE
DATA BASES
SPATIAL/ TABULAR DATA
GROWTH & YIELD AND PEST MODELS
PROJECTED STAND CONDITIONS
OTHER RESOURCE MODELS
RESOURCE OUTPUTS


SCALE 1:79200
0
1
2
3
STATUTE MILES
N
IDAHO
Sale Area Boundary
Prescription Watershed Boundaries
Predicted Mountain Pine Beetle Damage
Proposed Harvest Units

INTEGRATED INFORMATION TECHNOLOGY FOR NATURAL RESOURCE MANAGEMENT

Don O. Hunter, and
John E. Heasley
U.S. Fish and Wildlife Service
2627 Redwing Road,
Fort Collins, CO 80526-2899

William B. White
USDA Forest Service
3825 East Mulberry,
Fort Collins, CO 80524

Terry C. Daniel
University of Arizona
Tucson, AZ 85721

Gregory J. Buyhoff
VPI and State University
Blacksburg, VA 24061

ABSTRACT

Over the past few decades, natural resource agencies in the United States have amassed an unprecedented amount of data, and natural resource management has become increasingly complex. These conditions have rendered conventional resource-management tools and methods less effective. Resource managers are turning to more advanced information technology for help. This technology, however, is complex and seldom designed for natural resource management.

The INtegrated FOrest Resource Management System (INFORMS), a computer-based decision support system specifically adapted for natural resource management is described. Operating as an integrating shell, INFORMS can be configured to a user-specified geographic and problem universe. Once configured, INFORMS becomes a custom framework that supports a variety of decision support capabilities ranging from simple data storage and retrieval to sophisticated environmental analyses. INFORMS integrates the precise complement of spatial data, tabular data, and resource models needed to arrive at projected environmental consequences resulting from proposed management actions.

INFORMS was tested on the Red River District, Nezperce National Forest, Idaho. The data and models that were integrated included eight resource models, a multi-resource tabular database, and a spatial (map) database. Given the same type of analysis problem, INFORMS was more than four times faster than the conventional "hand" methods; consequently, more analyses were completed for a wider range of alternatives. It allowed greater flexibility for the forest manager to "fine-tune" alternatives for specific resource problems--with minimum staff involvement. The use

Hunter

of INFORMS on the Nezperce National Forest demonstrates that natural resource management can benefit from the integration and adaptation of information technology.

INTRODUCTION

Population increases, diminishing resources, a more concerned public, and burgeoning databases are pushing natural resource management (NRM) from the pencil age into the computer age. A typical national forest in the United States relies on about 40 different types of data embodied in databases, models, individual expert knowledge, or on map sheets--some forests have more than 13,000 maps on file in one office. Moreover, resource management decisions must consider biological, social, economic, and political influences. As the scope and complexity of NRM increase conventional information systems become less effective.

Recent advances in information technology such as geographic information systems (Burrough 1986, Optiz 1986), artificial intelligence programming (Stock 1987, Coulson et al. 1987), decision support systems (House 1983), new remote sensing techniques (American Society of Photogrammetry and Remote Sensing 1985), and new approaches for storing tabular data (Potter and Trueblood 1988) show promise for aiding NRM. Until recently, these technologies evolved out of separate needs and were applied separately. But with today's complex problems, more often than not, a combination of technology or systems is needed. Thus, the current trend is toward integration. Previously independent information technologies are being combined into single systems to create more powerful and versatile decision tools. For example, artificial intelligence is showing promise for enhancing geographic information systems (Robinson et al. 1986) and for modeling animal-environment interactions (Coulson et al. 1987). Also, several recent studies show very favorable results from combining artificial intelligence, geographic information systems, and remote sensing (Jackson and Mason 1986, Mckeown 1987, and Goodenough et al. 1987).

In this paper we describe the INtegrated FOrest Management System (INFORMS), a decision support system that integrates spatial data, tabular data, and resource models. We tested INFORMS on the Red River District, Nezperce National Forest, in central Idaho. INFORMS was faster than conventional "hand" methods; it allowed greater flexibility and repeatability for problem solving, and allowed managers to simulate complex ecological interactions while reducing the use of valuable staff time. INFORMS demonstrated that natural resources such as a national forest can be analyzed as an ecological system using integrated information technology.

The INFORMS concept of integration grew from work begun in 1983 (Daniel et al. 1984), which looked at the problem of assessing the impacts of forest pests damage using computer-based methods that interfaced with the forest-planning process. This work focused on developing a system that combined existing independent systems typically used

for assessing insect damage, such as timber-stand data, maps and geographic information systems, and models. From this work several development guidelines were recognized that later became the developmental framework of INFORMS. The system must at a minimum (i) communicate in language familiar to the user; (ii) produce the same results as the manual counterpart; (iii) be modular, allowing new models or other components to be linked as needed; (iv) support decisionmaking, not make decisions; (v) use common, standard file structures; and (vi) be easy to use, not placing a burden on the user to learn a complex system. Within the context of these guidelines INFORMS has evolved into an intelligent (following the problem-solving procedure of the human expert), flexible, problem-solving environment functioning much like an integrating shell. As such, INFORMS can be configured to different geographic locations and problem sets.

INFORMS

System Architecture and Operation

INFORMS is written in FORTRAN 77 and runs on Data General MV series computers. In its present form it is composed of four major system components: the central control module, the model library, the spatial component, and the tabular component (Figure 1). Figure 1 reflects INFORMS components specific to this study, another location with a different set of problems might require different components. General description and a discussion of each component's operation follow.

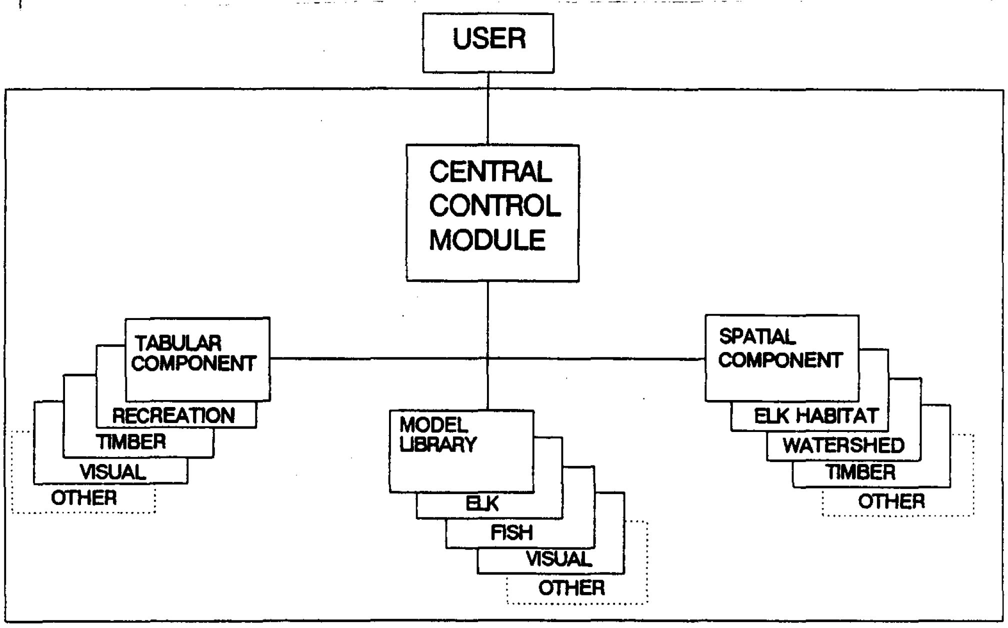


Figure 1. INFORMS system diagram showing major components.

Central Control Module. The central control module (CCM) is the system software manager. The CCM provides the architecture for linking all other components of the system and embodies the knowledge of which problem requires which component. The user interface is through the CCM, where user queries are converted into system instructions that define the bounds of the problem, perform analyses and present results. The user interface is menu-driven with text and graphics capability.

The CCM is composed of four submodules: (i) project definition, (ii)analysis specification, (iii) analysis execution, and (iv) report generation (Figure 2). The interactions of these submodules among themselves and with the other components are guided by programmed rules--techniques used in artificial intelligence that emulate the human problem-solving process.

The project definition submodule lets the user define the geographic extent of the problem. A project area is graphically defined by digitizing a boundary on the computer screen or by selecting a group of spatial entities (timber stand, watershed, etc...) that collectively represent a geographic area. The project boundary is used to delineate and extract the required geographic data from the spatial database.

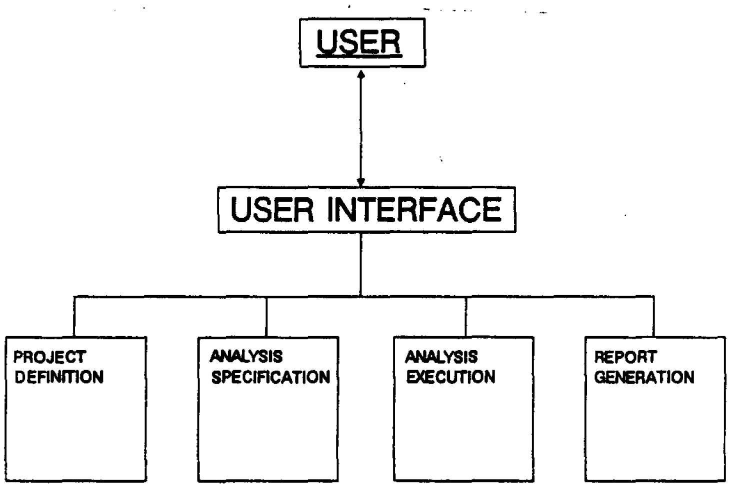


Figure 2. Diagram of the Central Control Module.

The analysis specification submodule allows the user to define the scope of the analysis and specify alternatives within each analysis. An analysis usually emphasizes a resource-management objective such as "minimize sediment yield," or "maximize economic return." For each analysis the user defines alternatives which are variations of the management objective. This submodule calls the appropriate models from the model library and initiates a data-preparation routine. After the data input requirements are determined for each model these input files are collated and all redundancies removed. A user

menu is then produced that is unique to that analysis scenario. Through this interface the user is prompted to enter additional information that characterizes specific management alternatives.

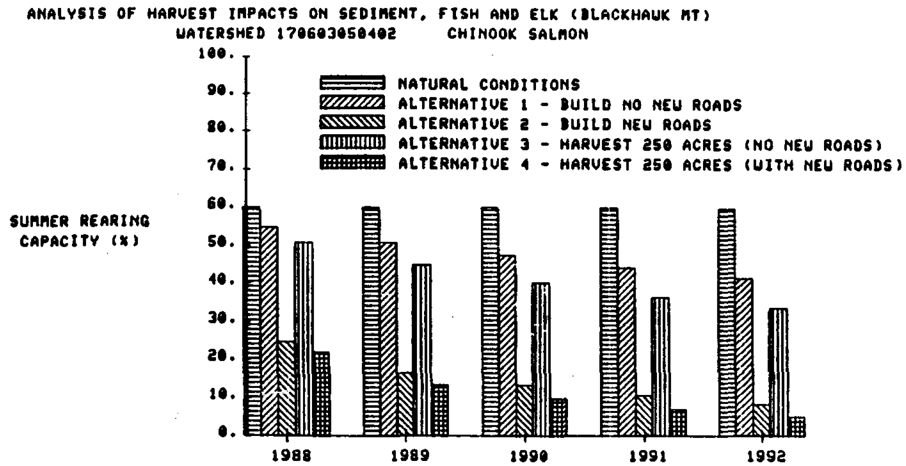
The execution submodule runs the complement of models selected during analysis specification. At this point the user further defines alternatives by selecting which alternative scenarios are to be executed and the time periods of each simulation. The models are then executed. Finally, the report generation submodule lets the user specify the type and format of the analysis products. The user specifies which analysis and which alternatives are to be reported. The final products can be tables, charts, or graphics (i.e., maps) (Figure 3).

Model Library. The model library is a collection of models (programs) that simulate resource responses such as forest stand growth, stream sedimentation, and fish production. Each model in the library consists of four interrelated submodules: simulation, input, output, and data preparation. The simulation submodule contains the equations and relationships that represent the observed natural phenomenon. It also reads the input information and stores the simulation results used by the output module or other related simulation models. The input submodule provides parameters that specify variable conditions (alternatives) for a simulation. Data for the CCM's report generation submodule is provided by the output submodule. Finally, the data preparation submodule manipulates the spatial and tabular data into specific formats required by each model. The CCM monitors and directs the interactions among the model library submodules.

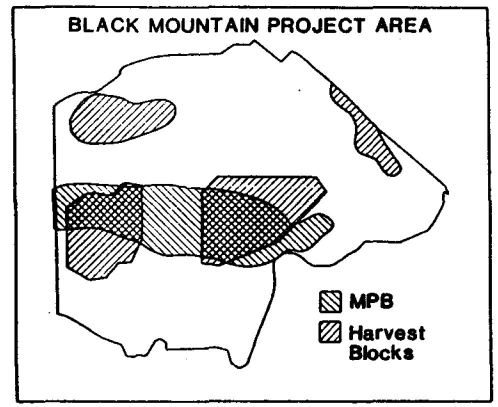
Spatial Component. The spatial component contains the spatial database and programs for manipulating and displaying spatial data. The spatial data are map files organized into themes such as moose habitat, soil type, roads, and timber stands. The number and types of themes are a function of the problem universe that INFORMS is configured to solve. The map files are stored in polygon format consistent with the Map Overlay and Statistical System (Lee et al. 1985), a general-purpose GIS used by the U.S. Forest Service and other Federal resource agencies. Each map file contains attribute data consistent with the input requirements of the models in the model library. For example, the number of miles of new road constructed on different soil types is needed for calculating erosion in the sediment model. These data are derived by overlaying a map of soil types with a map of proposed roads. The resultant map contains the required input fields needed to compute erosion.

INFORMS contains only the spatial analyses functions needed to support the user interface and model requirements. There are presently 17 commands in INFORMS including the more general GIS commands such as plot, distance, shade, buffer, and overlay (Heasley 1988). For added flexibility, however, it is possible in INFORMS to access MOSS directly.

a



b



c

ANALYSIS: ANALYSIS OF HARVEST IMPACTS ON SEDIMENT, FISH AND ELK (BLACKHAUK MT)
ALT: ALTERNATIVE 4 - HARVEST 250 ACRES (UITH NEU ROADS)

UATERSHED - 170603050403 RAINBOU STEELHEAD

YEAR	PERCENT OVER NATURAL	SUBSTRATE EMBEDDEDNESS	FINES BY DEPTH	EMBRYO SURVIVAL	SUMMER REARING CAPACITY	UINTER CARRYING CAPACITY
			(PERCENT)			
NATURAL	.00	23.23	18.50	75.26	96.59	45.39
1988	13.74	24.47	20.15	71.24	96.20	43.52
1989	13.73	25.70	21.80	64.89	95.79	41.73
1990	13.73	26.94	23.44	55.78	95.35	40.02
1991	13.73	28.17	25.09	44.37	94.89	38.37
1992	13.73	29.41	26.74	32.27	94.42	36.79

ENTER: (CR) CONTINUE, (1) EXIT, (2) NEXT ALTERNATIVE,
OR (3) REPORT OPT.

d

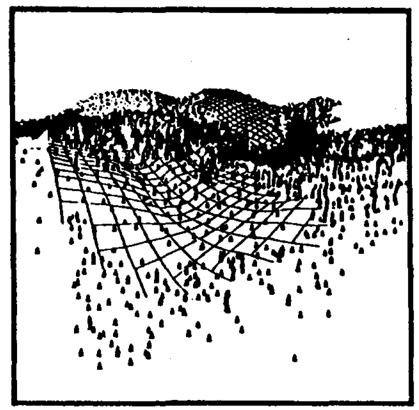


Figure 3. Examples of INFORMS output products: (a) summer rearing capacity bar chart showing effects of alternatives on chinook salmon, (b) map of Black Hawk Mountain project area showing MPB and proposed harvest blocks shaded, (c) winter carrying capacity table showing the effects of alternative 4 on rainbow steelhead, and (d) perspective view of project landscape after harvest.

Once in MOSS, the user can use all the features of the system.

Tabular Component. Functionally, the tabular component is similar to the spatial component; however, the structure and the source of the data are different. Tabular data such as timber inventory data and economic data are retrieved from databases (locally or remotely located) and manipulated or altered to meet model input or product output requirements.

INFORMS On The Nezperce National Forest

The Nezperce National Forest was specifically suited as a test site for INFORMS. Forest managers used spatial data, tabular data, and models independently to support their decisionmaking process. Also, the Nezperce is exemplary in terms of complex management problems. More than half of the forest's 1.9 million acres are available for commercial harvest. It is heavily used by recreationists. There are large herds of elk, *Cervus canadensis*, and mule deer, *Odocoileus hemionus*, and an increasing population of moose, *Alces alces*. In addition, it has two wilderness areas, and, on the Red River District (the study area) there is an impending outbreak of mountain pine beetle (MPB), *Dendroctonus ponderosae*, which threatens the reintroduction of anadromous fish into the Red River.

Successfully reintroducing anadromous fish into the Red River is an overriding management objective for the Forest. Formerly abundant throughout the rivers of Idaho, chinook salmon, *Oncorhynchus tshawytscha*, and steelhead trout, *Salmo gairdneri*, were severely reduced by dam building on the Columbia River. Today, the U.S. Forest Service is trying to reestablish these fish into historically used drainages such as the Red River. Salmon spawning habitat is very sensitive, thus every action that creates sediment or effects stream cover must be carefully analyzed--a complex and time-consuming process. For each proposed action, such as locating where to harvest 1.9 million acres of commercial timber, a multi-resource team of specialists must retrieve tabular data from various databases, hand draw and measure areas and distances from numerous layers of map data, and feed these spatial and tabular data into models that predict or simulate environmental consequences. The entire process can take weeks or months for each action and must be repeated if alternatives are considered.

System Configuration. For this application, INFORMS was designed and structured for general forest-management decision support, with specific modification for the MPB and anadromous fish problems. INFORMS on the Nezperce integrates the following: a multi-resource database, a spatial database (32 themes covering 20 1:24,000 U.S.G.S. base maps), and eight models (Figure 4).

INFORMS resides on a Data General MV series minicomputer at the Red River District office. A high-resolution graphics terminal is used to take advantage of all INFORMS functions. A version of INFORMS was loaded onto the

Forest's computer in 1987 where system evaluation and refinement have been a continuing process.

PROGNOSIS (Wykoff et al. 1982)	- simulates the size, structure, and yield of northern Idaho forest stands over time.
NEZSED (Cline et al. 1981)	- computes the amount of sediment delivered to critical stream reaches caused by fire, logging and road construction.
FISH (Stowell et al. 1983)	- simulates the response of salmonid populations to changes in sediment loading in streams.
ELK (Leege 1984)	- predicts the effects of road construction on elk use in northern Idaho.
COVER (Moeur 1985)	- projects the growth and structure of wildlife cover over time.
CONTAGION (Hamilton 1985)	- predicts the geographic spread of MPB over time.
DLOGPRICE (Artley et al. 1987)	- evaluates the economic viability of proposed timber sales.
VISUAL (Daniel and Itami 1988)	- computes the visual sensitivity of an area and visually displays projected changes to the landscape.

Figure 4. Models in INFORMS for the Nezperce National Forest application.

Figure 5 displays a generalized interactive dialogue between INFORMS and a user. In this example all models except Elk and Cover are used. First the project area is interactively defined by the user. The MPB model generates a map of the areas of predicted MPB spread, which is used as a guide for locating harvest units. Alternatives are created by varying the logging methods, spatial arrangement and timing for harvest, and the location and design specification for proposed roads. After the temporal scope is set, the models are run for these alternatives and the results reported to the user. Figure 3 shows some typical outputs from INFORMS. These products are identical to those produced by the independent systems integrated in INFORMS.

SUMMARY/CONCLUSIONS

By integrating models that simulate ecosystem responses to proposed actions, managers are able to gain a better understanding of the interrelations of the resources they manage. A synergy was noted using INFORMS whereby complex ecosystem interrelations were more realistically simulated through information system integration than through independent system use. Thus, the forest is more easily understood as an integrated ecological system rather than a mixture of separate, unrelated resources.

Models of natural resource phenomena are based largely on geographic parameters and relations. Data collection and input for executing these models independently over

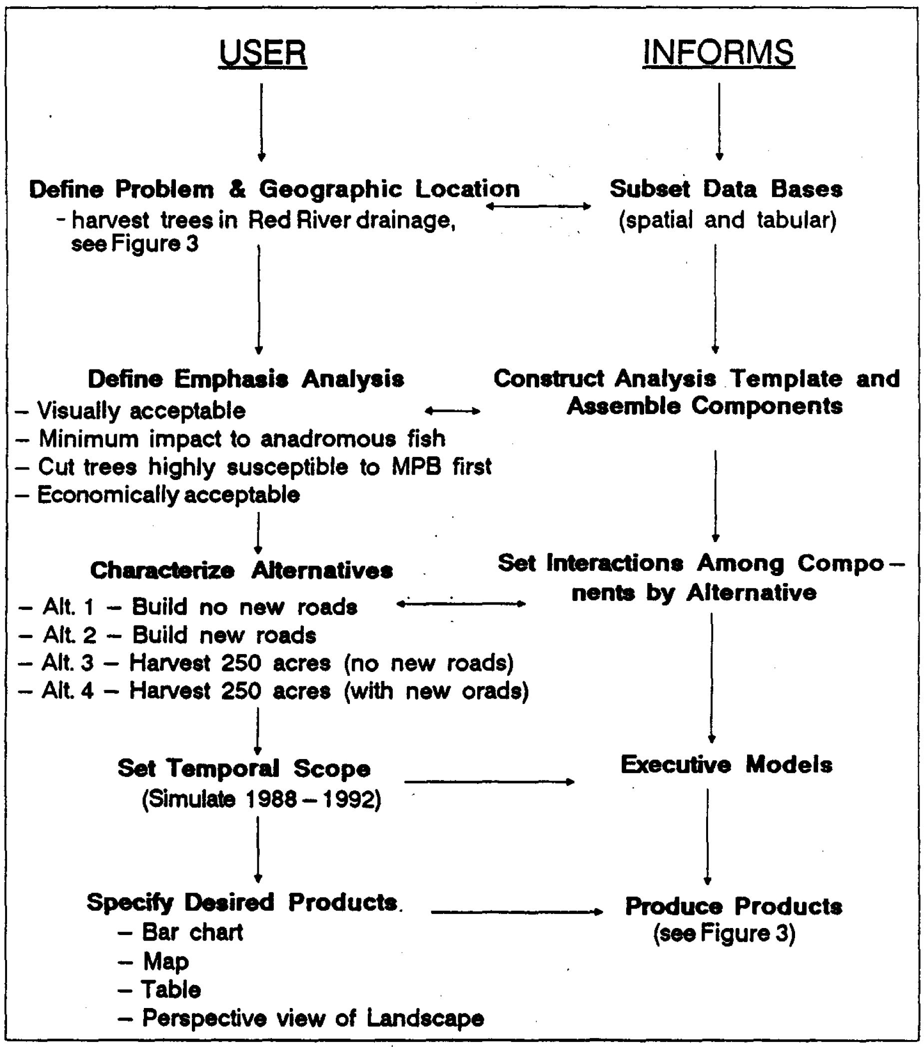


Figure 5. Generalized example showing the interaction between a user and INFORMS.

numerous alternatives is tedious and time consuming. Systems that automatically integrate spatial and tabular data with a library of models within an interactive shell can be cost efficient, more informative, and require minimal training.

The use of INFORMS on the Nezperce National Forest demonstrates that complex natural resource problems can be resolved easily and efficiently using an integrated approach to information technology. For more than a year INFORMS has been used in place of manual methods previously used. When compared to previously used "hand" methods, INFORMS was more effective, easier to use, required less

staff time, and was more flexible for aiding in a variety of problem-solving scenarios. Decisions could be reached three to four times faster (Bruce Short, personal communication), and with the increased speed and repeatability of environmental analyses, managers could "fine tune" their decisionmaking. The Nezperce prototype of INFORMS successfully demonstrated the viability of adapting new information technology to NRM and highlighted

integration as a precept of future NRM information management systems.

It further demonstrated that natural resources can be better understood and more efficiently managed by using integrated information technology. This technology, however, is rapidly changing as is the nature and scope of natural resource management; therefore, the development and calibration of systems such as INFORMS must evolve and adapt to changing needs and have the ability to take advantage of technology innovation.

REFERENCES

American Society of Photogrammetry and Remote Sensing. 1985. Symposium Proceedings - Pecora 10 Remote Sensing in Forest and Range Resource Management. Falls Church, Virginia. 616 p.

Artley, D., T. Erkert, and E. Butler. 1987. Handbook For Timber Sale Viability Analysis Using the "DLOGPRICE" Model on the Data General. Ms on file. USDA Forest Service, Northern Region, Missoula, MT. v.p.

Burrough, P. A. 1986. Principles of Geographical Information Systems for Land Resources Assessment, Clarendon Press, Oxford. 193 p.

Cline, R., G. Cole, W. Megahan, R. Patten, and J. Potyondy. 1981. Guide for Predicting Sediment Yields From Forested Watersheds. Ms on file. USDA Forest Service, Northern Region, Missoula, MT. 48 p.

Coulson, R. N., J. L. Folse, and D. K, Loh. 1987. Artificial Intelligence in Natural Resource Management. Science, Vol. 237, pp. 262-267.

Daniel T. C., and M. Itami. 1988. Visual Impact Assessment Module For the Integrated Pest Impact Assessment System. Progress report to USDA Forest Service, Forest Pest Management, Methods Application Group. Fort Collins, CO.

Daniel, T. C., W. B. White, and D. O. Hunter. 1983. Integrated Pest Impact Assessment System: An Interface to a Forest Management Information System. Methods Application Group, Forest Pest Management, U.S. Forest Service, Report No. 84-2. 22 p.

Goodenough, D. G., M. Goldberg, G. Plunkett, and J. Zelek. 1987. An Expert System for Remote Sensing. IEEE

Transactions on Geoscience and Remote Sensing. Vol. GE-25, No. 3, pp. 349-359.

Hamilton, D. B., J. E. Roelle, and W. B. White. 1985. Mountain Pine Beetle Damage and Contagion Modeling: Some Concepts and Approaches. USDA Forest Service, Forest Pest Management, Methods Application Group. Report No. 85-6. 25 p.

Heasley, J. E. 1988. Polygon Overlay: In Theory and Practice. 6th National Moss Users Workshop, New Orleans, LA. (in press).

House, W. C. 1983. Decision Support Systems - A Data-Based, Model- Oriented, User-Developed Discipline. Petrocell Books, Inc. Princeton, New Jersey. 486 p.

Jackson, M. J., and D. C. Mason. 1986. The Development of Integrated Geo-Information Systems. Int. J. Remote Sensing, Vol. 7, No. 6. pp. 723-740.

Lee, J. E., C. N. Reed, R. L. Frosh, L. C. Sullivan, and F. D'Erchia. 1985. MOSS User's Manual. Ms on file. U.S. Fish and Wildlife Service, National Ecology Research Center. Fort Collins, CO. v.p.

Leege, T. A. 1984. Guidelines For Evaluating and Managing Summer Elk Habitat in Northern Idaho. Wildlife Bulletin No. 11, Idaho Department of Fish and Game. v.p.

Mckeown, D. M., Jr. 1987. The Role of Artificial Intelligence in the Integration of Remotely Sensed Data With Geographic Information Systems. IEEE Transactions on Geoscience and Remote Sensing. Vol. GE-25, No. 3. pp. 330-348.

Moeur, M. 1985. COVER: A User's Guide to the CANOPY and SHRUBS Extension of the Stand Prognosis Model. USDA Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-190. 49 p.

Opitz, B. K. (editor) 1986. Geographic Information Systems in Government. Hampton, VA: A. Deepak Publishing. 968 p.

Potter, W. D., and R. P. Trueblood. 1988. Traditional, Semantic, and Hyper-Semantic Approaches to Data Modeling. Computer. June 1988. pp. 53-63.

Robinson, V. B., A. U. Frank, and M. A. Blaze. 1986. Expert Systems Applied to Problems in Geographic Information Systems: Introduction, Review and Prospects. Comput. Environ. Urban Systems, Vol. 11, No. 4. pp. 161-173.

Stock, M. 1987. AI and Expert Systems: An Overview. AI Applications in Natural Resource Management. Vol. 1, No. 1. pp. 9-17.

ACS/SSAC-M MANUSCRIPT SHEET To be reduced to 75% of original size

Stowell, R., A. Espinosa, T. C. Bjornn, W. S. Platts, D. C. Burns, and J.S. Irving. 1983. Guide For Predicting Salmonid Response to Sediment Yields in Idaho Batholith Watersheds. Ms on file. USDA Forest Service, Northern Region, Missoula, MT. 95 p.

Wykoff, W.R., N.L. Crookston, A.R. Stage. 1982. User's Guide to the Stand Prognosis Model. USDA Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report INT-133. 112 pp.

This is the bottom line of this page. Do not type or paste anything below this line.

Write Author's Last Name
Hunter